U.S. Army Corps of Engineers
Emergency Flood Fight Training Manual
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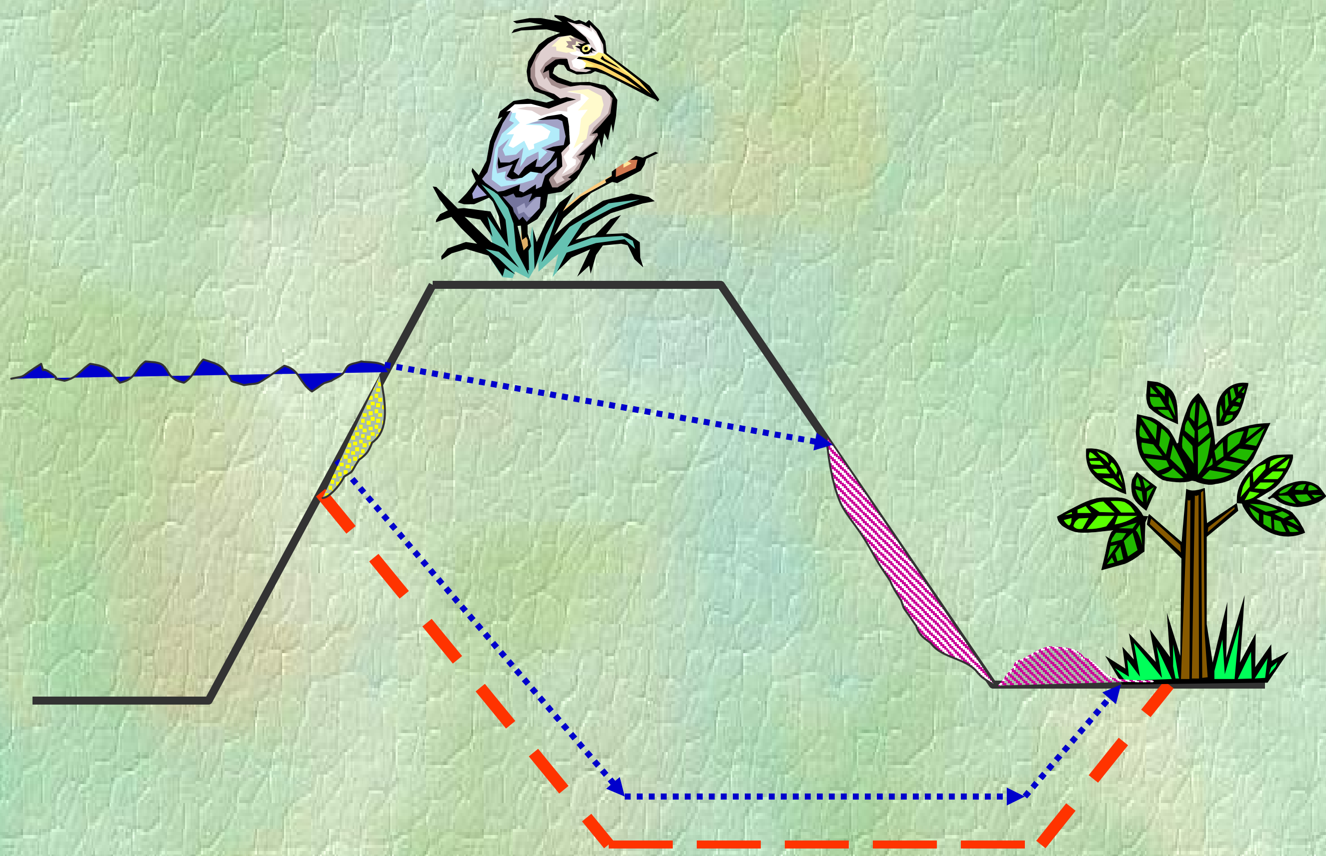

US Army Corps of Engineers®

U. S. ARMY CORPS OF ENGINEERS

EMERGENCY FLOOD FIGHT TRAINING MANUAL

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers has constructed numerous flood protection projects, primarily earth levees, designed to control and/or prevent damages caused by flooding. In addition to those projects constructed by the Corps, numerous communities and private individuals have constructed flood control levees to prevent flooding to residential areas and farmland.

Levee projects are quite common because they provide dependable protection, materials are relatively available, and they are relatively cheap to construct when compared to other structural options. Regardless of how well a levee system is designed and constructed, every levee system should be inspected on a regular basis and monitored prior to the flood season to ensure that problems, which could threaten the structural integrity of the system, are identified far enough in advance so that corrective action can be taken to prevent a failure. Proper maintenance of a levee system is extremely important because the consequences of a levee failure can, in some cases, be more damaging than the flood itself.

In order to assist those communities and individuals protected by levees, the U.S. Army Corps of Engineers has prepared this manual on emergency levee inspection, maintenance and repair techniques for use both in preparation prior to a flood event and during a flood event.

The ultimate goal of this manual is to assure that communities and individuals located in areas subject to flooding conditions are adequately prepared.

SECTION I

SCOPE & PURPOSE

A. SCOPE

The scope of this manual is generally limited to expedient flood fight techniques designed to modify and/or raise an existing levee to prevent failure during a flood event. The techniques described in this manual for raising an existing levee can also be used to construct a temporary levee system of protection to prevent flood damages in areas that are not protected by an existing levee. A glossary of terms used in this manual is presented as Exhibit No. 1, Appendix C. A list of acronyms is included as Exhibit No. 2, Appendix C.

B. PURPOSE

The purpose of this manual is to:

- Provide information on the types of assistance available from the U.S. Army Corps of Engineers prior to and during a flood emergency.
- Describe different types of failure modes that a levee can experience during high water events.
- Describe warning signs of various modes of failure a levee can experience during high-water events.
- Describe standard practices that have been successfully used in past flood fights for preventing various types of levee failure.

This manual is not intended to restrict flood fight personnel to standard techniques or a set of rigid rules covering every situation. Dangerous conditions not covered by the guidance presented hereinafter may arise, and such situations will require initiative and independent action on the part of the flood fight personnel. Normally, the procedures outlined in this manual should be followed. An emergency is not the time for conducting experiments or using untested methods.

SECTION II

GENERAL INFORMATION AND ASSISTANCE

A. U.S. ARMY CORPS OF ENGINEERS (USACE) - AUTHORITIES

USACE may provide emergency assistance under Public Law (PL) 84-99 Flood Control and Coastal Emergencies to save lives and protect improved properties (e.g. public facilities/services and residential/commercial developments) during or following a flood event. USACE emergency assistance will be undertaken only to supplement state, tribe, county, and local efforts. State, tribal and local interests must commit all available resources, e.g. work force, supplies, equipment, funds, National Guard assets, etc. as a general condition of USACE assistance.

USACE authorities consist of either technical assistance or direct assistance during flood response operations. Technical assistance consists of providing review and recommendations in support of state and local effort, and helping determine feasible solutions to uncommon situations. The following are examples of technical assistance: (1) guidance in flood fight techniques; (2) inspection of an existing flood control works project; (3) providing hydraulic and hydrologic analysis of the area; and (4) geotechnical evaluations of existing flood control works.

Direct assistance under PL 84-99 may include furnishing flood-fighting materials, e.g., sandbags, polyethylene sheeting, lumber, pumps, and riprap to stabilize eroding levees; contract hiring of equipment and operators for flood fighting operations or construction of emergency flood control projects; removal of log or debris jams that are blocking stream flow and causing flooding of communities, etc. Direct assistance under PL 84-99 is limited to flood related emergencies only.

Local entities desiring assistance from the Corps of Engineers for flood fighting should first go to their emergency disaster agency or other state/tribal agencies who are authorized to act for the governor / tribal chairman in times of natural disaster. The governor/tribal chairman, or an authorized representative, will request assistance for the applicable program from the Corps. Assistance under PL 84-99 cannot be provided directly to individuals.

A public sponsor can request flood emergency preparation assistance and rehabilitation of a flood control project threatened or destroyed by a flood. Public sponsors can be a legal subdivision of a state government, the state itself, a local unit of government, a state chartered organization or a qualified Indian tribe.

For further information on the Corps of Engineers assistance or eligibility for assistance during flood emergencies, contact the Readiness Branch of your local Corps of Engineers District Office. To find an address or telephone number for your local Corps of Engineers office, go to an Internet search engine and search for “Corps Districts”.

B. PRECIPITATION AND FORECASTING INFORMATION

Listed below are governmental agencies that can be contacted for information concerning pertinent stream flows, precipitation amounts, and forecasting.

1. NATIONAL WEATHER SERVICE (NWS)

NWS is the official forecasting agency. The NWS recommends sounding local sirens or other warning systems in case of inclement weather. Reference the following internet site for more information: http://weather.gov/ or http://www.nws.noaa.gov/.

2. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

NOAA provides continuous, around-the-clock broadcasts of the latest weather information directly from National Weather Service Offices by NOAA Weather Radio. Taped weather messages are repeated every 4 to 6 minutes and routinely revised every 2 to 3 hours, or more frequently, if needed. The broadcasts are tailored to weather information needs of the people within the service range of the transmitting station.

NOAA Weather Radio was designated the sole Government-operated radio system to provide direct warnings into private homes for both natural disasters and nuclear attack. This capability is to supplement warnings by sirens and by commercial radio and TV. NOAA Weather Radio broadcasts are made on one of seven high-band FM frequencies ranging from 162.40 to 162.55 megahertz (MHz).

162.400	162.425	162.450	162.475	162.500	162.525	162.550

These frequencies are not found on the average home radio now in use. However, a number of radio manufacturers offer special weather radios to operate on these frequencies, with or without the emergency warning alarm. Also, there are now many radios on the market that offer standard AM/FM frequencies plus the so-called “weather band” as an added feature. Reference the following internet site for more information: http://www.nws.noaa.gov/ or www.weather.gov see weather radio.

3. UNITED STATES GEOLOGICAL SURVEY (USGS)

The USGS provides daily streamflow conditions for each state. Reference the following internet site for more information: http://www.water.usgs.gov/ and the state steamflow conditions for each state at http://waterdata.usgs.gov/mt/nwis/rt.

4. U.S.ARMY CORPS OF ENGINEERS

4.1 MISSOURI RIVER BASIN WATER MANAGEMENT DIVISION (MRBWMD)

The MRBWMD operates the six dams that comprise the Missouri River Mainstem Reservoir System: Fort Peck Dam, near Glasgow, Montana; Garrison Dam, near Riverdale, North Dakota; Oahe Dam, near Pierre, South Dakota; Big Bend Dam, near Fort Thompson, South Dakota; Fort Randall Dam, near Pickstown, South Dakota; and Gavins Point Dam, near Yankton, South Dakota. The MRBWMD manages the mainstem dams during all flow conditions. Reference the following internet site for more information: http://www.nwd-mr.usace.army.mil/rcc/ .

4.2 DISTRICT OFFICE – WATER MANAGEMENT

Within each District Office of the U.S. Army Corps of Engineers, there exists a Hydrologic Engineering Branch that manages the release of water from the tributary sources. This section monitors, evaluates, and analyzes the Missouri River tributaries flow conditions. This section coordinates with the Bureau of Reclamation and the Denver, Colorado Water Board, and takes the lead when the water within the reservoirs are in flood pool. To find an address or telephone number for your local Corps of Engineers office, go to an Internet search engine and search for “Corps Districts”.

SECTION III

ASSESSING EXISTING CONDITIONS

A. GENERAL

At the beginning of every flood season, it is essential for individuals living in areas prone to flooding to establish an organization responsible for actions prior to and during flood emergencies. This organization should assign individuals directly responsible for various tasks during flood emergencies. The various tasks during a flood emergency will depend on site specific conditions but generally individuals should be assigned the following tasks:

1. FLOOD OCCURANCES: One or more individuals should be assigned to research and be aware of river stages, precipitation forecasts, snow melt runoff potential, and the potential for flooding.

2. INSPECTIONS: Inspections should be conducted at the beginning of every flood season and during flood events that cause water to come into contact with the levee. The purpose of the inspection conducted at the beginning of every flood season is to determine the existing condition of the levee and to repair areas that have been damaged or degraded in past floods to insure the functional ability of the levee system. Special attention should be made to all drainage ditches, drainage structures, flap gates and slide gates to ensure that all are functional and in good working condition. In areas that do not have a levee system, this inspection should be conducted to determine where a temporary levee structure would be constructed, where the upstream and downstream tie-off points would be, locate borrow areas or sources of material, and to make sure that the alignment area is clear of trees and other obstructions which would prevent the quick construction of a temporary levee during a flood emergency. The purpose of the inspection conducted during a flood event is to determine if problem areas are developing within a levee system or a temporary system which requires remedial measures such as a sandbag levee, mud box levee, or flashboard system.

The levee or line of protection should be broken up into segments with boundaries well defined. Usually, boundaries are established at landmarks such as bridges or drainage structures. This inspection should be conducted early in the spring before substantial vegetative growth occurs. Vegetation can, in some cases, hide the true condition of the levee and adjacent area. In areas that are protected by the preliminary levees, the individuals in charge of each levee section should conduct the preliminary inspection. Each individual should be given a large-scale map and a profile of his/her section. If profiles are not available, the necessary surveys should be conducted to determine the existing profile of the levee. Each individual should walk the entire length of his/her section, making detailed notes on the map. There is no better way for one not familiar with the territory assigned than to walk over the line as often as possible, studying the maps, and making careful notes thereon. An individual should be assigned the responsibility of inspecting each segment of the levee or line of protection. Aerial inspections can provide an understanding of the source and magnitude of flooding. Inspection checklists are provided on Plate Nos. 1, 2, & 3 in Appendix B to assist the inspector. All completed checklists and inspection documentation should be maintained in a file for future reference.

It is very important that the individuals responsible for inspections during flood events be familiar with the signs that occur prior to each failure mode. The different levee failure modes and signs, that indicate which failure mode is occurring are discussed in Section IV of this manual. Identifying which failure mode is occurring is important because the failure mode dictates which technique or techniques would be used in a flood fight.

Specific areas to inspect include the following.

LEVEE STRUCTURE

- Type of cross section; such as, trapezoidal, berm, etc.
- Condition of sod and growth of weeds.
- Debris on levee slopes.
- Local damage, such as wave-wash, rain-wash, and worn down ramps, etc.
- Evidence of previous high-water work, such as capping, earth blanketing, and ringing of sand boils, etc.
- Condition of existing seep drains on the landside slope.
- Damage to landside slope, such as where the toe of levee has been damaged by farm equipment or other machinery.
- Obstructions and crossing, such as siphons, pipelines, cables, railroads, power-lines, and fences, etc.
- Local depressions, such as old slides and depressions caused by subsidence.
- Type and condition of existing wave-wash protection.
- Condition of levee markers.
- Uncompleted levees.
- Condition of protective bulkheads, etc., around ends of levees.

- Condition of drainage structures including flap-gates, slide-gates, and inlet and outlet channels.

RIVERSIDE OF LEVEE

- Growth of trees and brush.
- Existing abandoned levees that may serve as wave-wash protection or as a source of material necessary for capping or blanketing.
- Spur levees – height and condition.
- Current scour around points, angles, and through openings that have been cut in abandoned levees.
- Landings and structures, etc.
- Caving banks.
- Condition of outfall drainage ditches.
- Secondary levees that may cause erosive velocities when overtopped, should be noted and monitored during flooding.

LANDSIDE OF LEVEE

- Seep ditch at landside toe – its condition and extent.
- Condition of culverts under roads adjacent to levee.
- Condition of seep ditch and culverts with drainage ditches.
- Condition of drainage ditches.
- Condition of natural drainage, ponded areas, and where drainage ditches connect with these areas.
- Local depressions near the levee where seepage water might be impounded.
- Sand boil areas.
- Possible landside borrow-pit areas for material necessary for sandbagging or capping.

- Condition of landward drainage ditches.

Inspection checklists as provided in Appendix B (Plate Nos. 1, 2, & 3) provide an excellent means to insure an adequate inspection and proper documentation of results.

3. INSTRUMENTATION: If instrumentation devices are present on a levee system, a team should be assigned the responsibility of data acquisition and evaluation. A properly designed, installed and maintained instrumentation program is a vital asset in the evaluation of the performance of a levee system both prior to and during a flood fight. Instrumentation such as survey points, piezometers, drains and relief wells provide key insight into the evaluation of a levee structure. Details of various instrumentation devices are presented on Plate Nos. 4, 5, & 6 in Appendix B. Typical data recording formats are presented on Plate Nos. 7, 8, & 9 in Appendix B.

4. FLOOD FIGHTING: A team of individuals should be assigned the responsibility of field flood fighting. These individuals should be fully aware of the techniques described in Section V of this manual.

5. EVACUATION: One or more individuals should be involved with executing the evacuation plan in the event that a levee failure becomes imminent. An evacuation plan should be developed prior to the beginning of a flood season and reviewed at the beginning of every flood season thereafter. The evacuation plan should be coordinated with the appropriate state and local authorities to ensure compliance with state and local laws.

6. RESCUE: A search and rescue team should be assigned in the event that a levee failure occurs or if personal injury is experienced during a flood fight operation.

B. AVAILABILITY OF LABOR, EQUIPMENT, MATERIALS, AND COMMUNICATIONS

It is very important that the availability of labor, equipment, materials and communication equipment be known prior to a flood emergency. It is very difficult to determine availability of these items in an emergency situation. Contacts should be made with responsible individuals to insure quick and easy access to these items during an emergency situation. The following is a checklist of items that should be evaluated prior to each flood season:

- ❑ Types and conditions of roads near and on the levee.
- ❑ Accessibility by roads to main arteries of traffic.
- ❑ Buildings that may be used as supply depots.
- ❑ Telephone, telegraph, and radio communications.

- Sources of emergency materials, supplies and labor.
- Types, locations, and general condition of levee building equipment.
- Types, locations, and general condition of motorboats that may be available for high-water service.
- Fuel supply stations and maintenance facilities.

C. REPORTS

Following inspections, a complete report should be made from the notes taken in the field and submitted to the individuals in charge of flood fighting. The report should be comprehensive and in sufficient detail to provide an accurate picture of existing conditions in the field. A brief summary should accompany the report from which local agencies may be advised as to the work required for them, and on the basis of which the district flood-fight organization may be expanded.

D. PRELIMINARY WORK

Prior to a flood season and after the preliminary inspection is completed, the following work should be performed as identified in the preliminary inspection report:

- Removal of weeds, unauthorized structures, fences, debris, and other obstacles which would hinder a flood-fight operation.
- Areas along the levee system, which have experienced current scour or wave erosion, should be filled with an impervious material such as silty clay or other clay type material and stabilized with riprap or fieldstones. Wherever new construction has been completed during the year, rain-washes with deep gullies may have developed. The necessary labor and equipment should be mobilized and serious deficiencies repaired. Gaps, where road crossings have worn the crown below grade, should be repaired. In filling the road crossing gaps, it may be necessary to obtain material from landside borrow pits in order to raise the levee sufficiently high. Any filling should be thoroughly tamped.
- All roads along the levee crown and on the levee berm should be put in a state of good repair. It may be found that many access roads previously used during the high water have been fenced off and are not now passable. These old high-water roads should be repaired and put in good condition by local officials. If the berm has been used for a road, the local officials should insure that the berm is in good condition and drains properly.
- All drainage ditches landward of an existing levee or landward of the alignment of a temporary levee location should be investigated and these drains should be opened where obstructions exist.

E. EVACUATION PLANS

Every community within an area that experiences flooding should develop an evacuation plan. An evacuation plan should even be developed for areas protected by levees or other flood control projects. Designated shelters, which are located above potential floodwater, should be a major component of the evacuation plan if such areas are available. Arrangements with the local army reserves and/or National Guard to obtain rescue equipment are also an important component of the evacuation plan.

SECTION IV

LEVEE FAILURE MODES

A. GENERAL. This section presents a description of various modes of failure that could be encountered prior to and/or during a flood event.

B. OVERTOPPING

Overtopping of a levee is the flowing of water over the levee crown. Overtopping may occur along an entire levee line or over local depressions in the crown. No matter to what small extent it may occur, the danger from overtopping is critical. The water flowing over the crown washes the material from the levee which could create a breach, or crevasse, in the levee line. Once a breach has been opened in the levee it is very difficult, and sometimes impossible, to close. It is, therefore, imperative that overtopping be prevented.

It is very difficult to predict in advance that a levee system will be overtopped. Therefore, it is imperative that as much information regarding river stages and predicted precipitation be gathered. It is also important that equipment, materials and labor are secured and readily available as soon as water is on the levee. The areas where overtopping would occur first should be identified and those areas should be monitored closely during a flood event.

C. WAVE-WASH

Wave-wash is the erosion of the soil slope of a levee by wave action. Passing boats, on-shore winds, or storms may cause the wave action. In any case, wave action may seriously damage a levee, particularly if the water surface is near the levee crown, or if the levee is newly constructed, or constructed of sandy soil.

If the slope is well vegetated, a storm of short duration should cause very little damage. Individuals responsible for inspections should determine beforehand as to the possibility of wave-wash. In all such reaches that can be determined in advance, filled sand bags and other material should be kept available for an emergency. During periods of high wind and waves, simple labor should stand by and experienced watchmen should observe by sounding the submerged slope with a long pole where the washouts are beginning.

In many cases, the necessity for wave-wash protection cannot be foreseen, and construction is often an emergency operation. The fluctuation of river stages as well as the uncertainty of weather conditions often make it impracticable to anticipate wave-wash damage, except for the assembling of necessary materials and supplies at convenient supply bases. A severe storm of a general nature may cause serious damage to the levee line. As it is impossible to predict the severity and duration of such storms, it is the duty of field forces to recommend construction of such protective works as are reasonably justified, and to hold themselves in constant readiness to meet emergencies as they appear.

D. CURRENT SCOUR

Current scour is the erosion of the riverside slope of the levee, the berm, and/or the adjacent borrow pit by abnormally high water velocities. Physical conditions that cause current scour are outside angles in the levee, waterway gaps that have been cut through abandoned levees, secondary levees, and topographical features which may create relatively deep channels adjacent to the levee during high water. Levees constructed across points of land are often subject to current scour as a result of the concentration of flow.

Scours are particularly dangerous due to the treacherous manner in which they develop and the difficulty of detection until almost irreparable damage has been done. The chief danger, of course, is that the scour will work into the levee slope. This type of scour resembles the caving bank of a river in action and appearance, in that it erodes under water and has a vertical caving face. When the water is near the top of the levee, and by the time the vertical caving face appears above the water surface, a large portion of the levee is gone.

Flood fight personnel must make careful observations of the riverside of the levee in the borrow pits in all reaches where an unusually fast current is apparent. For flood protection projects that have been designed using a hydraulic model, careful observations of the riverside of the levee should be made where the profiles show a steep high-water slope. Turbulence in areas where the water is shallow is a pretty good sign of no scour, but should be watched. If the turbulence unexpectedly becomes quite, scour may be suspected and soundings should be made immediately. Conversely, in deep water, scour mat be indicated by turbulence and eddies. Field personnel should be particularly watchful for such conditions. If erosion is evident, immediate steps should be taken to protect the levee.

E. THROUGHSEEPAGE

Throughseepage is the percolation of water through the levee structure. Although not dangerous in itself, the seepage may decrease the stability of the levee by saturating the soil causing instability of the landside slope.

Throughseepage usually appears in the seep ditch at the landside toe of the levee. As the water rises against the levee, the seepage flow increases. As long as the wetted area is relatively small, no action, other than keeping the water drained away from the levee by means of small seep drains in the landside slope, will be necessary. If the levee becomes saturated over a relatively large area, it may become necessary to take other precautions to prevent sloughing. Blanketing of the riverside slope to reduce the seepage is the most satisfactory treatment, although this may be combined with the construction of buttress work on the landside, or the installation of drainage wells, if such action appears necessary.

Seepage through a levee system can also occur along drainage structures or result from improperly adjusted or damaged drainage structure gates.

Leakage caused by improperly adjusted or damaged gates should be identified in the preliminary inspections prior to every flood season and corrective actions taken.
Leakage through drainage structures as a result of improperly adjusted or damaged gates will probably not fail the levee system. In many cases, time will be better spent flood fighting in areas where a levee failure could occur.

F. UNDERSEEPAGE

Underseepage is seepage water yraveling through the foundation, usually near the landside toe of the levee or appearing as a spring or sand boils in ditches, borrow pits, or other depressions landside of the levee. Water that issues from sand boils flows through pervious strata under the levee and then breaks through the surface cover, washing with it material from beneath the levee base. A sand boil may gradually undermine a levee and result in a failure by causing sudden subsidence of the levee.

It is difficult to evaluate the seriousness of sand boils. Consequently, all sand boils should be watched closely. Any boil that enlarges and increases its discharge of material, especially if located within 200 feet of the levee toe, is considered to be a threat to the levee and should be controlled. Treatment of boils, however, is not limited to those within 200 feet of the levee toe. Incipient boils should be marked conspicuously with flagging on a stick so that patrols can locate them without difficulty and observe changes in their conditions. A boil which discharges clear water in a steady flow usually is not a serious menace to the safety of the levee. The only action necessary in this case is to make careful frequent observations of the boil and to drain the excess water off to prevent its impoundment near the levee. However, if the flow increases and in addition carries a material load of sand and silt, corrective action should be taken immediately to prevent levee failure.

G. SUDDEN DRAW DOWN

Distress due to sudden draw down results in the sloughing or sliding of the riverward side-slope of a levee after the flood waters recede. This condition develops in levee systems constructed of impervious material, such as clay, which become saturated during a flood and the floodwater recedes faster than the levee can drain. During the period that the flood water is receding, the riverward side slope should be inspected closely for cracks and slides to determine if corrective actions should be taken.

H. BURROWING ANIMALS

Burrowing animals can severely threaten the integrity of a levee system and these animals need to be controlled.

Animals of particular concern are the pocket gopher, ground squirrel, badger and fox. The most common is the gopher, which pursues activities mainly underground and is seldom seen on the surface. It seems the gopher prefers a sandy soil to other types.

The burrow openings, created by most of the animals observed on the levee, are approximately 3 inches in diameter and are evidenced by a mound of fresh earth 1 to 2 feet across. The opening is always filled with a few inches of loose earth, probably to exclude sunlight. The burrow is a system of runways, side branches, food storage, and nesting chambers, with numerous openings to the surface spaced very close together. The chambers or burrows may have a depth of several feet.

During periods of flood, the river water and the seep water drive the animals to the levee from the adjacent low areas. Since the gopher never stays above ground, it immediately burrows into the levee and overnight may honeycomb the levee with runs. As the water rises, new runs are opened higher on the levee and the old ones are left open for water to enter. When a run or system of runs below the water elevation happens to connect from landside to riverside, the water literally pours through the levee.

SECTION V

FLOOD FIGHT METHODS

A. GENERAL.

This section presents a discussion of general practices, which have been used successfully during high water conditions to maintain and prevent levee failure. The methods described herein have been developed during many years of experience dealing with the problems that may arise as a result of high water. Conditions and problems may arise which are not completely covered by the suggestions provided. If problems do arise that are not adequately covered in the document presented herein or there is doubt as to the proper procedure to be taken, the sponsor should immediately consult the local USACE District Office for advice and assistance as necessary.

The local sponsor is responsible for project maintenance during high water events. A plan for such maintenance activities should be developed well in advance of the normal flood season and updated as necessary to account for changes in personnel responsible for maintenance activities. The plan should include an adequate warning system and a well thought out evacuation plan to be followed should the need arise during the life of the project. Upon receipt of official information forecasting the possibility of high water, the sponsor should immediately mobilize a skeleton organization capable of rapid expansion. Definite reaches of the project should be assigned to individuals (section leaders). Each section leader should immediately go over the entire assigned project reach and make a detailed inspection giving special attention to the following:

- Section Limits: Ascertain that dividing lines between section responsibilities are clearly defined and if necessary marked.
- Condition of the drainage ditches, levee, and any recent repairs.
- Conditions of drainage structures with special attention given to flap gates.
- Water conditions and any accumulations of trash, debris, ice, etc.
- Transportation Facilities: Vehicular roads and access.
- Material Supply: Location, item, quantity and conditions.
- Communications: Locate and check all necessary two-way radios and telephones.

After the initial inspection, each Section Leader should recruit a labor gang and perform the following work as required:

- Fill holes, gullies and washes in the levee crown and slopes. Farm equipment can be used in repairing these small deficiencies.

- Repair all gaps or depressions which have degraded or are lower than the original levee grade. Filling such depressions may necessitate using material from borrow pits in which case excavation for the material should be kept at 500 feet from the toe of the levee. This type of filling should be tamped in place and, if subject to wave wash, the new section should be faced with sandbags.

- Check all flap gates to see that they will set properly.

- Ascertain that necessary access roads along the levee are usable or will be satisfactorily conditioned.

- Locate necessary tools and materials (sacks, bags, brush, lumber, lights, etc.) and distribute and store same at points where active maintenance is anticipated.

- Check all needed telephone lines for proper functioning. Obtain lists of all team forces, construction equipment, motorboats, motor cars and truck transportation that can be made available.

- Arrange with local citizens for supply, transportation, subsistence and shelter for labor force.

- Examine all drainage ditches on the land side of the levee and remove any obstructions.

- Remove all dynamite and explosives from the vicinity of the levee.

A maintenance inspection should be made of all drainage structures any time high water stages are forecast. No structure should be omitted from such inspection because of adequate performance during past high water events. If any condition is found which would indicate that the flap gate will not properly operate, the gate should be trial operated at once. Most drainage structures are situated to convey interior drainage from low points of the protected area through the levee by gravity flow. Because of location, drainage structures are generally subject to inundation at lower stages than most other project features. If possible, sluice gates should be inspected before the outlet end of the structure becomes submerged and any trash, debris or other potential obstruction present should be removed. If, for any-reason, the gate system provided on a drainage structure fails to operate and cannot be repaired because of high water, immediate consideration should be given to blocking the structure opening by other means. Blocking of the outlet end of the structure should be given first consideration if stream stages permit. Timber, metal plates, or a tarp covering held in place by sandbags are suggested methods of providing an effective temporary closure. If the efforts to plug the outlet structure fail, immediate action should be taken to build a sandbag or earth ring around the inlet structure. While it is of the utmost importance that the structures are blocked to prevent high stages of the river from flowing into the protected area, such emergency closures should be such that they can be readily removed after high river stages recede.

An earthen levee is in potential danger whenever there is water against it. The danger increases with the height of water, the duration of the flood stage and the intensity of either the current or wave action against the levee face. A well constructed levee of correct cross section should, if properly maintained and not overtopped, hold throughout any major flood. Potential failures due to sand boils, sinking levees, slides or sloughing may be prevented if prompt action is taken and proper methods of treatment are employed.

B. OVERTOPPING

Overtopping is the rush of flood waters over the top of the levee section. The practice of increasing the height of a levee by placing material on the crown to prevent overtopping is called capping or topping. In any high-water situation, sound practice requires that immediate consideration be given to the levee grade line. Although grade lines or profiles should be keep current, a new line of levels (survey) should be run over any reach that appears to be below the predicted flood crest. If the necessity for capping is made evident by the preliminary inspection, the grade line to which capping is to be constructed will be established by the U.S. Army Corps of Engineers, District Engineer, if requested by the local project sponsor, or to a grade line approximately two feet above the predicted crest height of the flood event. This grade, for the top of the capping, should then be furnished to flood fight construction unit supervisors.

The grade, in general, is based upon a freeboard approximately 2 feet above the anticipated elevation of water. Field supervisors should use a certain amount of judgment in determining the type and extent of capping. For example, if the profile shows that a stretch of levee requires less than ½ foot of capping to provide the desired 2 feet of freeboard, the capping may be temporarily omitted. If, however, 2-½ feet of capping is necessary and only 12-inch boards are available, three boards should be used, although the earth needs to be built up to a height of only 2-½ feet. In general, a tolerance of ½ foot above or below the prescribed grade is permissible.

Since capping should be as nearly watertight as possible, care should be taken in preparing the portion of the crown of the levee upon which capping rests. All depressions, such as paths or ramps, should be restored to the natural levee grade, with adequate cross section. Sandbags are frequently used to bring low ramps up to grade as shown on Plate No. 10. The levee crown should be thoroughly scarified to a minimum depth of 2 inches by plowing, or other similar means, in order to obtain a watertight bond between the capping and the levee crown (levee surface).

There are generally four types of capping as follows:

- earth-fill
- sandbag
- flashboard
- mud-box or box levee

The type of capping required is governed by local conditions. Earth-fill capping is the simplest type and quickest to construct. In areas where cohesive materials are unavailable and where the capping would not be exposed to severe wave wash, earth filled capping can be used to a height of approximately 1-½ feet. In areas where cohesive materials (such as clay) are available, greater heights can be achieved, depending on wave action and current velocities. If the levee crown width is 20 feet, or more, the height to which earth levee capping can be placed may exceed 1-½ feet. Under usual conditions where the height capping exceeds 1-½ feet, and is less than 3 feet, or where wave action is anticipated, sandbags or flashboards can be used to raise the level of protection. Capping in excess of 3 feet in height usually requires mud-box or box levee construction, depending on the width of the levee crown and the nature of the material used for capping. Under conditions where capping is necessary over previous high water capping, care should be taken to provide adequate base width for the new work. The height controlling the type of structure should include the height of previous capping. That is, if the combined height of new and old capping exceeds 1-½ feet, flashboard capping should be used. In such cases, it is often necessary to resort to the mud-box or box levee type structure in order to provide adequate stability. The construction methods for each type of capping will be described in the order mentioned above.

1. EARTH-FILL CAPPING

Earth-fill capping consists of a small embankment constructed on the crown of the existing levee. After all local depressions have been prepared as described previously, the crown of the levee is thoroughly scarified by plowing, or other method which overturns the earth to a minimum depth of 2 inches. An earth-fill is then constructed to the required height with its riverside edge 1-½ feet from the riverside edge of the crown. The crown of the fill should be level transversely, and the side slopes should not be steeper than the natural slope of the angle of repose of the material used. The 1-½ feet on the riverside edge of the crown is reserved for placing earth-filled sacks for wave-wash protection, if necessary.

The method of placing material in the earth-fill varies with the locality and circumstances. Speed is essential and the more use that can be made of machinery, with a corresponding savings in hand labor; the more quickly the job will be completed. The use of lumber fences and/or boxes will greatly reduce the amount of earth required.

The material may be placed by hand from wheelbarrows or tractor-drawn scrapers, trucks, clamshell or dragline machines may be used to place material in the cap. Where the crown of the levee is more than 15 feet in width, the material can be rapidly and economically bladed from the landside edge of the crown into the fill by means of a road grader. Where the crown width is less than 15 feet, usually the material can be readily and relatively cheaply placed by a dragline or clamshell machine obtaining material from borrow pits located landward of the levee. Ordinarily, material shall not be taken from within 100 feet of the landside toe of the levee. As this material is usually wet, more than one lift may be required before the required height of fill is obtained. For bringing capping material up from the landside of the levee, tractor-drawn scrapers or trucks are probably the fastest and the most satisfactory method of transportation if conditions are such that this sort of equipment can operate. Trucks are fast, but can operate only when the levee is dry and when well-constructed ramps are available. Tractor-drawn scrapers can operate under more adverse conditions than trucks but are not satisfactory for extremely wet and soggy levees. For extremely bad conditions, the relatively slow and expensive method of bringing the material up the land slope of the levee in wheelbarrows must be used. The earth-fill type of capping is ordinarily recommended only for levees having a crown 10 feet or more in width.

Listed below are two methods of placing materials for an earth-filled cap:

1.1 Capping (Topping) With Hauling Equipment.

This method should receive first consideration in raising long low stretches of levee known to have insufficient freeboard to safely withstand predicted stages, provided the work is done well in advance of high stages. No heavy equipment should be allowed on the levee when the water is near the top as the vibration might cause a failure, especially to sandy soils. An ideal outfit for this work consists of a small dragline capable of transportation by heavy-duty trailer, a fleet of trucks, and a bulldozer. The material dumped on the levee crown should be spread in layers not exceeding 1 foot in thickness and thoroughly rolled by bulldozer. Loaded trucks should be run over the topping as the work progresses to give additional compaction. Great care must be exercised in traveling up and down landside slopes to avoid damage to the slope or sod and in no case may be done when the levee has commenced to seep.

1.2 Cut Crown Topping.

This form of topping, which consists of shifting material from the landside edge to the riverside edge of the levee crown, should never be used except as a last resort when material cannot be secured from other sources. When this method is used, care must be taken to disturb as little of the sod as possible and to excavate in such a manner that throughseepage does not become a problem. Small draglines may be used on a wide levee crown.

Earth-fills used to increase the level of protection for a levee are very susceptible to wave and runoff erosion. They are also very limited to the height they can be constructed to, therefore, the degree of protection they can be expected to provide is limited.

2. SANDBAG LEVEE CAPPING

Sand bag levee capping as shown on Plate No. 11 is a dependable method and has been used over the years. An excessive amount of labor; however, is required and progress is relatively slow. Due to the increasing scarcity of labor, flood fight teams should use faster, more efficient methods whenever possible.

The base area available limits the height of a sandbag capping; therefore, a levee can usually be raised only a few feet by this method. In general, the base width of a sandbag levee cap should be three times the height of the cap.

The following is a description of the proper steps required to construct a sand bag levee:

- The foundation where sand bags are to be placed should be scarified. This will provide for a good bound between the ground surface and the sand bags and reduce the amount of seepage that could occur between the ground surface and the first row of sand bags.
- A key trench should be dug in the center of the proposed sand bag alignment. This trench should be approximately 2 bags wide and I bag deep.
- Before placing sand bags in the key trench, plastic sheeting should be placed in the bottom of the trench. This will reduce the amount of seepage that would occur between the ground surface and the first row of sand bags.
- Sand bags should be filled one-half to two-thirds full.
- If the bags are filled at the site of placement then the bags should not be tied. If the bags are to be filled off the site and transported to the placement site then tying the bags will prevent losses due to spillage.
- Start placing sand bags in the key trench on the plastic sheeting.
- Place the filled bags length-wise and parallel to the direction of flow. Lay the unfilled portion of the bag flat on the ground.
- Place the succeeding bags on the unfilled or tied portion of the previously laid bag and stamp into place to eliminate voids and form a tight seal.
- Stagger the joint connections when multiple layers are necessary and stack the sand bags in pyramid fashion.
- A good rule of thumb is to construct the sand bag levee base width three times the sand bag levee height.

The following is an estimate of the amount of sand and the number of sand bags which are required to construct a 100-foot linear sandbag capping:

Height	Sandbags Required	Tons of Sand Required
I Foot	800	13
2 Feet	2,000	33
3 Feet	3,400	56

The basic disadvantage of this type of capping is it is very time consuming and labor intensive. It also requires a fairly large base width that may not be available.

3. FLASHBOARD AND MUD BOX CAPPING

Flashboards and mud boxes are similar in that they are both constructed of wood and are usually reinforced with some type of earth-fill. The use of flashboards and mud boxes in connection with earth-filled caps serves several purposes. They protect against wave-wash, reduce the amount of topping material required, provide for greater heights with lesser base widths, make the topping material more impervious and generally provide a more stable structure. Typical flash board capping is illustrated on Plate Nos. 12 through 16 in Appendix B.

Flashboards are generally used for heights up to 3 feet. For heights over 3 feet, it is probably more economical to construct a mud box instead of a flashboard.

3.1 Flashboard Capping.

If the capping required exceeds 1-½ feet, and is less than 3 feet, or if the capping is likely to be exposed to wave action, flashboard capping is used. This work consists of a board fence built about 1-½ feet from the riverside edge of the levee crown with an earth-fill placed on the levee crown landward of the board fence.

Flashboard capping is usually divided into two classes; two-board and three-board The two-board levee capping is used in situations that require less than 2 feet of capping but require protection for the capping against wave action. The three-board levee capping is used in situations that require more than 2 feet, but not to exceed 3 feet of capping. The method of construction for both classes is fundamentally the same. The accepted method and sequence of operations in constructing this type of capping are as follows:

- A furrow is plowed or dug into the levee crown about 1-1/2 feet from the riverside edge. The earth dug from the furrow should be deposited landward of the furrow so that the bottom board will fit flush against its riverside edge. The furrow should be as straight as practicable; avoiding abrupt turns, and should not be less than 2 inches deep. The bottom of the furrow should be as level as practicable in order to provide a secure and even seat for the bottom board of the fence.

- The next step is to place the bottom l-inch by 12-inch boards on edge in the plowed furrow, placing them end-to-end.

- The 2-inch by 4-inch posts are then driven to a penetration of about 24 inches on the landside of the 1-inch by 12-inch boards, wedging the boards against the riverside edge of the plowed furrow. The 2-inch by 4-inch posts should be placed at intervals of approximately 5 feet so that the ends of the boards will lap on a post, the length of the boards usually determining the intervals between posts. In general, the posts used in flashboard capping should extend at least 1 foot above the top of the proposed upper flashboard, to provide for the placing of an additional board in case of necessity. Tops of posts should be roughly chamfered before driving.

- After the bottom boards have been nailed to the posts, the furrow is backfilled with loose material that is thoroughly tamped against the bottom boards on both sides.

- Additional boards are then placed and nailed to the posts. Particular care should be taken to break the joints on the posts. If necessary, additional posts may be driven to take the laps of additional boards. It is practicable to build this type of capping up to three boards in height.

- The levee crown landside of the capping is scarified by plowing or other methods that overturn the earth to a minimum depth of 2 inches. This is very important in order to provide a good bond between the levee crown and the new earth-fill.

- Burlap, plastic sheeting, tar paper, or other type material is then placed on the landside of the flashboards in order to prevent the loose earth-fill from being washed out through the cracks between the boards.

- Earth-fill is placed on the landside of the flashboards to the desired height.

- If three-board capping is used on a narrow crown levee and the toe of the slope of repose of the earth-fill would fall beyond the landside edge of the levee crown, it is necessary to add a board fence near the landside edge of the levee crown. The landside fence is constructed in the same manner as described for the riverside fence. The posts are placed on the landside of the boards and are tied to the posts of the riverside fence by 2- by 4-inch braces. Generally, the height of the landside fence is one or two boards less than that of the riverside fence.

- An alternate method of constructing flashboard capping is to place the 2-inch by 4-inch posts on the riverside of the 1-inch by 12-inch boards. The first described method is preferable since the bottom boards are wedged tightly against the riverside edge of the plowed furrow and permits less seepage than does the alternate method. However, an advantage in placing the 2-inch by 4-inch posts on the riverside of the I-inch by 12-inch boards is that the pressure of the earth-fill is transmitted directly from the boards to the posts. Also, with this method, flashboard capping can be converted into a box levee, if necessary. If the alternate method is used, it is very important that the loose earth on the riverside of the 1-inch by 12-inch boards be thoroughly tamped against the boards.

3.2 Mud Box Capping.

In capping to a height greater than 3 feet, or in capping a narrow crown levee, the mud box levee type of capping is used as illustrated on Plate Nos. 17 and 18 in Appendix B. The work consists of building board fences near both the riverside and landside edges of the levee crown, and placing earth-fill between the two fences. This fill should be earth well tamped and should never be earth-filled sacks. Where possible, the width of mud box levee capping should be twice the height of the earth-fill. An accepted method of constructing a box levee is as follows:

- A furrow is plowed along the levee crown, about 1- ½ feet from its riverside edge, as described above.
- The bottom boards are placed on edge in the plowed furrow, end to end, along the levee.
- The 2-inch by 6-inch or larger posts are then driven to a penetration of about 3 feet on the riverside of the bottom boards. The posts should be spaced at intervals of approximately 5 feet so that the ends of the boards will lap on the posts. Tops of posts should be roughly chamfered before driving.
- After the bottom boards have been nailed to the posts, loose earth is thoroughly tamped against the bottom boards on both sides.
- Additional boards are than placed and nailed to the posts, joints being broken on the posts.
- Plowing, or some other method, which provides a good bond between it and the fresh fill, scarifies the levee crown.
- The landside fence is constructed in the same manner, except that the posts are placed on the landside of the boards.
- The posts of both fences are then tied together with 2-inch by 4-inch horizontal braces.
- Burlap, plastic sheeting, tar paper, or similar material is placed on the landside of the riverside fence.
- Earth-fill is placed between the fences.

- If the height of the earth-fill is to exceed 4 feet, the box levee should be reinforced by driving additional posts to support the fences.

- In constructing a mud-box or box levee across an old slide, depression, or on levees having a narrow crown where it may be impossible to obtain the standard height-width ratio (I to 2), the box levee should be strengthened with additional bracing. The strength of the members used for bracing and their disposition depend entirely upon local conditions. If possible, the additional braces are placed outside the mud-box or box levee, bracing it to the landside slope of the levee. If outside braces are impracticable, the mud-box or box levee is bolstered by braces within the box, placed diagonally from the top of the riverside fence to the bottom of the landside fence.

4. CAPPING MATERIAL

4.1 Sources.

The usual sources of earth-fill for capping are from the farm fields landside of the levee, from the banks of drainage ditches, or from the landside edge of the crown when the levee has a crown in excess of 15 feet in width. Ordinarily, material should not be taken from within 100 feet of the landside toe of the levee. In taking material from cultivable fields, care should be exercised not to damage them any more than is absolutely necessary. It is customary to take a cut only about one spade deep over a relatively large area.

4.2 Placing.

The method of placing material for capping is important in order to minimize the amount of seepage through the capping. The material adjacent to the flashboards should be free from sods and stubble and should be thoroughly tamped. All additional material should be compacted as well as conditions permit.

5. CONDUCT OF WORK

The supervisors in charge of capping should organize crews so that the work will proceed in a regular order, each crew of men executing a particular phase of the work, such as preparing and distributing lumber, plowing, setting posts, nailing boards, placing burlap or other materials, and placing the earth-fill. If long stretches of levee are to be capped to a given height in the face of a rapidly rising river, it is well to set the posts to the required height and place the bottom boards only. Succeeding boards and fill are placed after the first boards have been placed throughout. Capping work should be laid out so that the low places are concentrated on and a uniform freeboard provided, parallel to the anticipated flow line, throughout the entire length of the job. The exact method of conducting this kind of work depends upon local conditions and upon the best judgment of those in charge of the work.

These methods of capping are fairly labor intensive and costly. They are also very susceptible to wave erosion if the waves break at the intersection of the flashboard and the levee. If this case arises, protective measures should be executed to ensure that the flashboard or mud box is not undercut. The protective measures for wave erosion are discussed later in this section.

C. WAVE-WASH & ICE ATTACK

The type of wave-wash protection to be constructed depends upon local conditions, whether or not the levee is exposed to severe wave-wash, the materials of which the levee is constructed, the type and quantity of trees and protective vegetation which may be expected and the existing and predicted stages of the river. The types of wave-wash protection generally used are vertical board revetment, horizontal board revetment, and earth-filled sack revetment. Each of these types is described below. Sometimes ice conditions are such that protection provided by the methods outlined above will not be totally effective. A boom of logs, driftwood, or any available timber fastened together, strung along the levee slope and anchored about 15 feet from the water's edge has proven particularly effective against ice attack.

1. VERTICAL BOARD REVETMENT

The vertical board type of wave-wash protection is preferred in all localities where the wave action is, or is expected to be, severe. On higher levees; however, this method is impracticable, as the length of boards, the length of braces, etc., would be prohibitive, both in cost and time of construction. The toe of the vertical board revetment generally should be placed in about 1 foot of water and the top should extend about 2 feet above the predicted high-water stage. The accepted method of constructing this type of revetment is described as follows: (See Plate No. 19, Appendix B.)

- Either 2-inch by 6-inch posts or larger are driven to a minimum penetration of 3 feet, 6 inches and battered to a slope of about 6 vertical on 1 horizontal. They are usually placed on 7-foot centers. Tops of posts should be roughly chamfered before driving.

- Braces 2-inches by 6-inches or larger are fastened to the posts as indicated.

- Braces are then secured by anchors constructed of 2-inch by 4-inch lumber.

- A 2-inch by 6-inch top whaler is placed as indicated in the detail. A bottom rail of the same size is placed just above the existing water level and secured to the posts.

- Next, I-inch by 12-inch boards are driven to a minimum penetration of 2 feet and are securely attached to the top and bottom rails by 16d common nails. The boards are driven close together so that the width of cracks is kept to a minimum.

- If the height of the 1-inch by 12-inch boards above the ground surface exceeds 10 feet, a third 2-inch by 6-inch whaler is placed between the top and bottom whalers.

2. HORIZONTAL BOARD REVETMENT

The horizontal board types of wave-wash protection is used in cases where it is necessary to provide a minimum of protection for levees that are not directly exposed to attack and are partially protected by timber growth. This type is suitable for use on levees where the levee is not exposed to sustained wave action over extended periods. This type of protection can be placed with a relatively small crew and is suitable in case of an emergency along a long levee line, even if some of it later requires replacement with a sturdier type of protection work. The accepted method of constructing the horizontal board revetment is as follows: (See Plate No. 20, Appendix B for details).

- Posts of 2-inch by 4-inch lumber, or larger, are driven at the water's edge to a minimum penetration of 2-1/2 feet, being battered on a slope of about 6 vertical on I horizontal. The posts are placed at intervals of approximately 5 feet so that the ends of the boards will lap on the posts, the lengths of the boards determining the intervals between posts. Tops of posts should be roughly chamfered before driving.

- Braces of 2-inch by 4-inch lumber are fastened to the posts as indicated.

- The braces are secured by at least three 2-inch by 4-inch anchor stakes, which are driven to a minimum penetration of 2 feet. The anchor stakes are fastened to the braces.

- Boards of 1-inch by 12-inch material are placed on the riverside of the 2-inch by 4-inch posts and are nailed securely. The bottom boards are embedded in the levee slope as well as practicable before additional boards are placed. Additional boards are placed to approximately I foot above the predicted water level. Particular care is taken to break the joints of additional boards on the posts.

- Earth-filled sacks are used to fill local scour holes under the bottom boards. One or more rows of sacks are placed against the landward side of the bottom boards to prevent undermining at the base.

3. SACK REVETMENT

Sacked earth material should be used only as a means of minor wave-wash protection, or to fill local holes that are washed in the levee by wave action. The sacks should be placed close together beginning about 2 feet under the water surface. Each succeeding row of sacks should overlap the preceding row like shingles on a roof. Care should be taken to stagger the joints. All sacks should be tamped or mauled into place so that the wave action will not readily wash the sacks away.

Sacking for wave-wash cannot be placed effectively in advance in the face of a rising river since the cutting action is at the water surface. Before the sacked zone can be made effective, the water level will rise above and overtop the upper sacking.

The accepted method of constructing a sack revetment is shown on Plate No. 21 in Appendix B.

4. SLOPE PROTECTION

4.1 RIPRAP SLOPE PROTECTION

Rock riprap is a very popular method to prevent wave-wash erosion and current scour. Depending on the haul distance, this method can; however, be very costly.

Although not covered in this manual, if site conditions and time permits, the use of filter fabric and / or bedding and spalls placed prior to riprap should be considered to prevent soil material from being pulled through the riprap layer.

4.2 OTHER METHODS.

Straw bales wrapped with polyethylene sheeting on the waterside can be used to provide some wave-wash protection as shown on Plate Nos. 23 through 25 in Appendix B. Sand bags should be used to weigh the bales down so they don't float away.

5. STEEL PILING REVETMENT

Under certain conditions, it may be necessary to construct a steel-piling revetment. This method is shown on Plate No. 26 in Appendix B.

D. CURRENT SCOUR

The methods to be used in protecting a levee against current scour depend entirely upon local conditions. In some cases, the current attack is so severe, and the scour is of such serious nature, that it requires specially designed structures that cannot be constructed with the ordinary high-water-fighting equipment and personnel. Ordinarily; however, current scour can be prevented or stopped by relatively simple techniques. The methods which can be used to prevent current scour are widening of waterway gaps in abandoned levees, protecting the riverside slope of the levee with riprap or wave-wash fences, or the construction of brush dikes, each of which is discussed below. If the protective measures mentioned above are not effective in preventing current scour, the U.S. Army Corps of Engineers upon request could provide assistance.

1. WIDENING OF WATERWAY GAPS

Widening the gaps and degrading abandoned levees to the extent necessary can reduce high current velocities against a levee, caused by narrow waterway gaps through abandoned levees. Waterway cuts at both the upper and lower ends of old levees should be widened sufficiently, to reduce the current velocity to that which will not cause erosion. This operation can be accomplished during high water only by floating equipment; dragline or clamshell machines on barges.

2. PROTECTING SLOPE OF ERODED LEVEE

In cases where minor current attacks are evident on the levee slopes, especially on newly constructed levees, the riverside slope should be protected from current action either by means of riprap or by means of vertical board wave-wash protection, both of which are described in this section under wave-wash. The current protection work should extend as far under water as practicable in an attempt to restore the original levee cross section. The vertical board protection should be placed as close to the original riverside toe of the levee as practicable and sacked earth material should be placed at the base.

3. BRUSH DIKES

In cases where other protective methods will not obtain the desired results and where it becomes necessary to deflect the current away from the levee or to reduce the flow adjacent to the levee, it becomes necessary to construct brush dikes as current deflectors. In any particular instance, local conditions will determine the position, specific location and design of the brush dike. Several dikes may be required to stop scour. The first dike should be constructed below the scour, working upstream into and above the scour with additional dikes.

There are two types of deflection dikes, Type "A" (Plate No. 27, Appendix B) and Type "B" (Plate No. 28, Appendix B). Both of these dikes are constructed in the same manner, except that Type "A" requires the use of wire mesh in order to retain the riprap stone in place when used instead of sacked earth or sacked gravel. In general, a simple brush dike is constructed in the following manner.

- A double line of 4-inch by 4-inch or 3-inch by 6-inch posts are driven on 4-foot centers, the lines of posts being about 4 feet apart and at the designated angle to the levee. The posts should be driven to the maximum practicable penetration, with their tops approximately 2 feet above the anticipated high-water surface.

- Each pair of posts is braced laterally with 2-inch by 6-inch, or larger, cross-braces so placed that a runway may be constructed on top of the braces. In deep water, additional diagonal braces should be placed on the downstream side of the dike, bracing the downstream line of posts to the ground. Such braces should be of 2-inch by 6-inch material and should be driven at a 45-degree angle with the posts, to a minimum penetration of 3 feet. The dike may be strengthened by driving an additional row of posts on the downstream side of the dike, bracing them to the dike with 2-inch material.

- The brush dike frame is filled with alternate layers of willows, or some other suitable brush. Sacked earth, sacked gravel, riprap stone, or concrete is used to hold the brush in place. Heavy lumber should be used for braces and walkway to support the movement of materials. The first layer of filler should consist of earth-filled sacks, being so placed as to level out the irregularities in the bottom and to provide a smooth base for the brush filler. The brush filler should consist of bundles of brush and poles, laid so as to form a solid mat. The brush should be rammed tightly into place. Each layer of brush should be about 2 feet in thickness and should be weighted down with one or two layers of sacked earth. The brush and sack filler should extend about I foot above the anticipated elevation of the high water.

- A mat of earth-filled sacks to retard scour is placed at the outer end of the dike.

- Unless a floating plant is available, the driving of posts should be commenced at the inshore end of the dike and carried progressively to the outer end of the dike. The posts may be driven with mauls or by means of a "dolly" (See Plate 14, Appendix B). As each pair of posts is driven and braced, the driving crew moves forward by means of 2-inch by 12-inch plank runway placed on the horizontal braces, and the next pair of posts is driven. Tops of posts should be roughly chamfered before driving.

- The placing of brush and sacked earth filler should be undertaken along the full length of the dike simultaneously. The filler should be placed in approximately horizontal layers beginning at the deepest water and progressing upward to the required height of the dike. In localities where trees of suitable dimensions are readily available, round timbers may be substituted for the square posts and braces described above.

4. STONE CRIBS

For control of scour along the levee slope or in the borrow pits near the levee, the use of stone or riprap cribs as shown on Plate No. 29 in Appendix B and as described in the next paragraph, is very effective. The cribs should be placed in the scour hole with the concentration of load in the direction of the levee to insure that further scour development will be away from, rather than toward, the levee. The cribs can be constructed at the site on the levee or bank and pushed where needed by bulldozers.

Cribs are usually 14 feet by 14 feet by 18 inches outside dimension constructed of double thickness 1-inch by 4-inch by 14-foot lumber, equivalent to 2-inch by 4-inch pieces, lapped rail fashion at all corners and intersections. The cribs are divided into four compartments by two cross walls constructed in the same manner as the sidewalls. The floors and covers of the cribs are built up of double 1-inch by 4-inch boards spaced about 9 inches center to center. Under the floor, and perpendicular to the direction of the floorboards, are five equally spaced pairs of 1-inch by 4-inch boards about 2-1/2 feet center to center. On top of the cover, perpendicular to the direction of cover boards, are three pairs of top boards, placed over each sidewall and the partition wall. The covers can be built directly on the crib, or separately, and placed on the crib. In either case, the cover is placed after the crib is filled with rock. All intersections are nailed with one 20d nail and each intersection of walls or fabricated crib is securely fastened by a loop of 3/8-inch strand, tightly twisted. The wire loop is put in place loosely before filling with rock and twisted into place to include the top after it is in place.

The 14-foot by 14-foot by 18-inch crib will hold approximately 5 tons of stone. The weight can be adjusted as desired to meet existing conditions by increasing or decreasing the depth of crib.

If stone is not available, the cribs may be filled with sacked earth or gravel, broken concrete, or other suitable material.

In launching the cribs, it is sometimes advisable to tie them together to keep them from separating and so they will help pull each other off the bank.

The use of stone-filled cribs has been very effective in retarding the caving of banks. The size of the crib is not necessarily standard. It may be necessary to make heavier or smaller cribs to accomplish the mission. Each condition of emergency must, of course, govern the plan of operation.

After construction of the stone-filled cribs, launching or placing them properly becomes critical. To be most effective, the cribs or whatever substitute has been devised must be fastened to each other with a cable in a sort of string-out.

If the caving bank is not inundated, the construction, assembly, and launching of the cribs can be accomplished from the top of the bank. Power tools and other equipment, such as cranes and bulldozers, would be used in this case. Where the caving is entirely under water, a floating plant will be needed for the operation. The number of cribs in a string-out must be governed by factors such as working room, time, rate of caving, and possibly other conditions peculiar to the location.

E. THROUGHSEEPAGE

1. SEEP DRAINS

Drainage of the landside slope of the levee is one of the most important high-water maintenance operations. Consequently, the function must be fully understood and appreciated. Drainage of the adjacent terrain is also highly important.

The methodology utilized in draining the slope is to concentrate the flow of seepage into directed channels that carry it rapidly down the slope and away from the levee. The result is that the slope will often become dry and firm between the drains. The drains themselves sometime never stop flowing. Drainage alone sometimes will not stabilize a wet slope and the slope could become unstable. If this happens, watch the slope carefully for signs of sliding or sloughing and be prepared to construct a mattress immediately.

Water seeping through a levee may first appear as a wet spot on the slope. As the seepage increases, the wet spot spreads in size until the whole slope is wet and the seep water slowly flows down in a sheet. Continued exposure will cause the slope to become more and more saturated and soggy until it is liable to slide or even flow out resulting in a levee failure or requiring extreme measures to prevent a failure.

To prevent sloughing of the levee where the slope is steep and saturated, small "V"-shaped seep drains should be cut in the landside slope to remove the seepage water. These drains may be cut diagonally down the levee slope and should not be more than 4 inches in depth. Several diagonal drains may be led into one drain running straight down the levee as shown on Plate No. 30 in Appendix B. Horizontal drains should not be used, and extreme care should be taken not to disturb the sod unnecessarily outside of the seep drains.

The work consists of opening and clearing the various ditches so that seep water or rainwater will have a free flow from the levee into drainage ditches which convey the water to the drainage structures through the levee. If drainage is perfected prior to high water, the effectiveness of the drainage system will be far greater than if the work is attempted after the ground has become saturated. During flood events, the gates on the drainage structures should be closed to prevent floodwaters from inundating the protected area landward of the levee. This condition may cause runoff water to pond behind the levee until the floodwaters recede. If the water behind the levee begins to cause damages it should be pumped across the levee to the riverward side.

The first drains should be cut 12 to 15 feet apart, V-shaped, no more than 4 inches deep. The drains should originate at the upper or highest limit of seepage and run straight down the slope and lead across the landside berm into a drainage system. To secure better coverage of the seeping area, additional drains spaced 4 feet to 6 feet should be cut between the first drains.

The above-described method of drainage is applicable to clay, loam, and sandy loam levees only. It should not be used as a means of drainage on sand levees, or where the foundation supporting the levee consists of sand. On sand levees, the seep drains should be omitted and the seepage allowed to "trickle" down the landside slope to the seep ditch paralleling the levee toe. If seepage through a sand levee is excessive, a blanket of loamy material should be placed on the riverside slope.

If additional excavation is necessary to provide adequate drainage, the general plan described in the above paragraph, should be followed as closely as practicable. The material excavated from the seepage ditches should be deposited on the side away from the levee, and material excavated from the off-take ditches should be deposited in such a manner that it can later be used as material for capping, if necessary.

In no case should an attempt be made to cut slope drains until seepage actually appears. All traffic, animals and personnel should be kept off seeping side slopes.

2. SLOUGHS AND SLIDES

Where seepage appearing high on the levee slope cannot be controlled by seep drains as outlined in the preceding paragraph, and the condition grows progressively worse, there is danger that a slough or slide may develop. A slough is a condition in which the slope is excessively wet and soggy and is inclined to flow or fall away from the slope and heave or pile up at the toe. A slide is more apt to occur on steep slopes even when the soil does not appear to be extremely wet. In a slide, the slope breaks away in a clearly defined crack or cleavage plane and moves outward taking the toe of the embankment.

In any case, where it appears that slope failure is likely or has occurred, the recommended treatment is reinforcement in the form of a buttress on the berm below the slide, tapering up over the failure. A brush or board mattress is always placed under the buttress and constructed in such a manner that it will permit drainage, provide a stable but flexible base for distribution of uniform pressure, bridge the failure, and anchor it against further movement.

Plate Nos. 31, 32, and 33 in Appendix B illustrate methods of construction of a brush mattress and two types of board mattress.

2.1 BRUSH MATTRESSES

After slope drains have been cut as shown on Plate No. 31 in Appendix B, place a single layer of standard willow brush or several inches of small trees or limbs with butts up the slope and tops down and perpendicular to centerline of levee. The brush should extend onto the dry slope several feet above the soft area and far enough onto the berm landward of the levee to provide a base for the buttress. A second layer of poles or brush is cross-laid over the first layer to help distribute the load and to prevent sacks from falling through. In preparing brush for a mattress, all leaves and small twigs must be removed to prevent stoppage of drains.

The mattress is then loaded with sand-filled or gravel-filled sacks or riprap in the form of a buttress as required to hold the failure, having the heaviest part of the load on the berm, not more than one layer near the top and no load at the very top.

Great care should be taken when placing the second and third layers of sandbags because placing these layers too far up the slope can actually add load to the slide area causing additional movement.

2.2 BOARD MATTRESS - STANDARD TYPE

When brush is not available or impracticable to obtain, a board mattress may be constructed instead of the brush mattress as shown on Plate No. 32, Appendix B. Any width of I-inch lumber may be used, but either 6-inch or 8-inch widths will probably be more available than other sizes.

To construct a standard type board mattress begin by first draining the levee slope and berm, as described above, making the slope ditches 3 to 6 feet on centers. Lay a board over each drainage ditch up and down the levee slope and as far across the berm at right angles to the levee as considered necessary to hold the slope mattress in place. Fill in between the first boards with parallel boards up the slope and across the berm leaving about 1-inch cracks between boards.

Place the top layer of boards across the bottom layer and parallel to the levee leaving about 2-inch cracks beginning at the toe of levee and working up and down. The top boards should be randomly nailed to the bottom boards with at least two nails to each board. On levee slopes of 1 vertical on 3 horizontal and steeper, 2 by 4's should be placed about every 3 feet in the top layer to prevent the sacks from slipping down.

The mattress is then loaded in the same manner as the brush mattress.

2.3 BOARD MATTRESS - STRINGER TYPE

For a condition known as "dry slide" in which the landside levee slope breaks away and moves out but is not excessively wet or soggy and simple reinforcement or buttressing is indicated, the stringer-type board mattress can be used effectively as shown on Plate No. 33 in Appendix B.

The method of construction is similar to the other board mattress except 2-inch by 4-inch lumber is used for the bottom layer instead of 1-inch lumber. Drain the slope as in the other method with ditches 2 feet on centers. Then lay one 2-inch by 4-inch, 4-inch side down, between each drain running up the levee slope to a point several feet above the slide and well out onto the berm. Lay the 1-inch lumber across the 2 by 4's, nailing as required to hold in place.

The mattress is then loaded in the same manner as the brush mattress.

2.4 BLANKETS

In the event that the seep drains do not prove to be effective and the landside slope of the levee shows definite indications of sloughing, it will become necessary to blanket the riverside slope. Plastic sheeting can be used to retard seepage. Sandbags are used to anchor the plastic sheeting. For underwater placement, sandbags are tied to the corners of the sheet and at intervals in between to hold the sheet tight against the slope. Sandbags are then placed into the water allowing the them to sink to the toe of the levee.

Seepage that occurs along a drainage structure can be stopped most effectively by placing plastic sheeting around the outlet of the structure that is located on the riverside of the levee on the upstream and downstream levee slopes from the drainage structure.

If it becomes necessary to prevent leakage through a levee system as a result of improperly adjusted or damaged gates, the outlet on the riverside of the levee should be covered with a row of sand bags and plastic sheeting. If the water level on the riverside of the levee prevents this, it may be necessary to plug the inlet to the drainage structure on the landward side of the levee. This is much more difficult than plugging the outlet on the riverside of the levee. Any measure used on the landward side of the levee will probably leak and it may become necessary to pump the water back over the levee once it collects in the drainage ditches on the landward side of the levee.

F. UNDER-SEEPAGE

Excessive underseepage can result in what is known as a sand boil. The following is a discussion of methods to treat sand boils. Piping is an extreme condition caused by excessive underseepage in which foundation materials (soil) are transported from beneath the levee. Unless corrective actions are taken, a solution channel or “pipe” may develop and enlarge to the point where the levee could fail. Early treatment of sand boils found to be transporting soil materials is the best insurance against a piping condition from developing.

1. LOWER POOL LEVEL.

The most effective method of controlling a sand boil is to reduce the head of water on the riverside of levee as shown on Plate No. 34. This method; however, is not normally practical because it would take construction of a set back levee to eliminate or lower the river elevation.

2. SACKING OF SAND BOILS

The most widely accepted emergency method of treating a sand boil is to construct a ring of sacked earth/sand around the boil, building up a head of water within the ring sufficient to check the velocity of flow and prevent further erosion of sand and silt. This method is illustrated on Plate Nos. 35 through 39 in Appendix B. The ring should not be built to a height that stops the flow of water because of the probability of building up an excessive local pressure head, causing additional failures and boils nearby.

2.1 METHOD OF RINGING SAND BOILS

The accepted method of ringing or sacking a sand boil is described below and shown on Plate No. 35 in Appendix B.

- The base of the sack ring is prepared by clearing the adjacent ground of debris, vegetation, or other objectionable material, to a width sufficient for the base of the ring. The base should then be thoroughly scarified to provide a watertight bond between the natural ground and the sack ring (a very important step).

- The sacks are laid in a general ring around the boil, with joints staggered and with loose earth as mortar between all sacks. In general, it has been found that the best results can be obtained by commencing construction of the sack ring at its outer edge and working toward the center.

- The ring is carried to a sufficient height to stop the flow of soil from the boil. Work is stopped when clear water only is being discharged.

- A V-shaped drain constructed of two boards or a piece of sheet metal should be inserted near the top of the ring to carry off the water. A spillway made of sandbags can also be used to discharge water from the sandbag ring.

2.2. DIMENSIONS OF SACK RING

It is impossible to establish exact dimensions for a sack ring. Field conditions in each situation will govern. The diameter of the ring, as well as its height, depends upon the size of the boil and the flow of water from it. Field forces should determine the size of the ring upon consideration of the following:

- The sack ring should have sufficient base width to prevent side failure. The width should be determined by the contemplated height of the ring, and should be not less than 1-1/2 times the height.

- The enclosed basin should be of sufficient size to permit the sacking operations to keep ahead of the flow of water. If ground weakness is indicated close to the sand boil, it is well to include the weak ground within the ring, thereby avoiding the possibility of a breakthrough later.

2.3. SACKING METHODS VERSUS SAND BOIL LOCATION

Sand boils at the toe of the levee are sacked in the same manner as those away from the levee, using the levee slope as one side of the enclosure as shown on Plate Nos. 38 and 39 in Appendix B. The seep drains on the levee slope should be constructed to drain the water from the sack ring.

If several sand boils appear within a relatively small radius, it is better to enclose the entire group in a sub-levee or single sack ring.

If sand boils break out in very low ground or deep ditches, it may be necessary to step down the head of water within the enclosure in two or three steps, by means of outside concentric rings, to avoid a "blowout" near the ring.

3. INVERTED FILTER

An inverted filter as shown on Plate 40 in Appendix B is an expedient and economical means to control excessive seepage such as sand boils. A fine sand and/or filter fabric is normally placed over the seepage area with successively larger granular material placed on top. The section will allow the seepage water to be safely removed while holding down or trapping the fine soil material preventing the development of a piping situation.

4. CORRUGATED SHEET-STEEL PILING

An alternate method of ringing sand boils is by the use of corrugated sheet-steel piling as shown on Plate No. 41 in Appendix B.

Using sheet-steel piling accomplishes the same task faster than sandbagging but is limited in use by the availability of material, equipment and location of boils.

However, as previously stated throughout this manual, circumstances will dictate the system or method most applicable.

G. LEVEE BREAKS

1. CLOSURE OF BREAK IN LEVEE

Where it is practical and desirable to do so, closure of a break in a levee will reduce the period of inundation of the property inside of the levee, prevent the break from widening, and reduce the damage caused by subsequent rises that may occur before the levee can be repaired. For Federally constructed projects, the U.S. Army Corps of Engineers, District Engineer will make determination if a break should be closed.

Generally, a break closure should not be attempted on a rising river stage or on an extremely high stage. Conditions could develop such that it would become impossible to accomplish the closure. The time to attempt a closure is on a falling river stage when the velocity and turbulence of the flow through the break has decreased sufficiently to assure complete success of the effort.

There are undoubtedly several acceptable methods of making a closure. However, each closure must be considered as a special case depending on the general location, size, river stage, economics, and the health and safety of the general public.

Seepage through and under a levee may be controlled to prevent a levee failure from occurring, however, a significant quantity of water may pond on the landward side of the levee with no place to drain to. In this situation, pumping may be used to prevent damages caused by seep water.

2. STRUCTURE AND PLAN FOR CLOSING A LEVEE BREAK

One levee closure plan, which has been developed and successfully used by the Corps of Engineers, is detailed in the following paragraphs. It should be considered for use, only under specific situations where the plan and general conditions are complementary and not as a standard procedure for all closures.

The structure is composed of two parts:

- A timber trestle filled with sandbags to shut off the free flow of water

- An earth-filled mud box landward of the trestle to reinforce and make the structure watertight, constructed in that order as shown on Plate No. 42 in Appendix B.

A scour hole usually forms in the break slightly landward and enlarges to the landside. The closure structure should be located far enough away from the edge to allow for enlargement of the scour hole and the structure may be placed either on the landside or the riverside of the crevasse depending on which has the shallower water and the least amount of obstructions. The ends of the structure should join the existing levee well back from the edges of the break to allow for caving while the closure is being built. Trees should be cut off just above the water surface to prevent any movement of sandbags caused by trees swaying in the wind.

The closure should never be started until all required labor and material are available at the site so that closure can be made without interruption. The delay of a few minutes at a critical time may mean the loss of the closure.

Closing a levee break entails considerable danger to personnel working on the closure. Handrails should be installed where needed, the project should be well lighted and employees should wear life vests when working near water. At least two boats, equipped with oars and ring buoys with hand-lines, and manned at all times by experienced operators, should be anchored just below the levee break. An experienced first-aid team equipped with first-aid equipment should be available at all times.

In areas where soil material and earthmoving equipment are available, the levee closure can be constructed of earth.

3. TIMBER TRESTLE

The components of the timber trestle and mud box levee closure are described below:

- Drive four 4-inch by 4-inch upright posts spaced as shown. The mud box post is lower than the trestle posts; it should be about 6 inches above the water.

- Nail a 2-inch by 6-inch crosspiece on each side of the three trestle posts at the top and one 2-inch by 6-inch crosspiece from the center post to the mud box just above the waterline.

- There should be four runways, two along the top of the mud box and two along the top of the sack trestle. Each runway consists of two 2-inch by 10-inch boards laid side by side. The runway boards are projected beyond the last bent so men can stand side by side to drive the posts of the next bent. Bents are spaced 4 feet on centers.

- Five stringers are placed. One each under the cross-piece on the landside posts, center posts, and riverside posts, and one each just above the waterline on the center posts and the riverside posts.

- Hog wire netting is strung along the riverside of the center posts and nailed to the lower stringer by 40d nails; the lower edge of wire is extended across the bottom of the trestle so it will be held down by sacks when they are dropped on it.

- One-quarter inch wire strand braces are placed on the trestle part of each bent, as shown on the plan, but not on the mud box posts.

- Sufficient filled sacks should be stockpiled to complete the closure; because once this operation is started, it must not be stopped until completed. The first sacks are distributed across the bottom and banked against the hog wire. The dam is then brought up on a level grade so that the flow of water is distributed evenly over the entire length. The crest can be brought above the water surface first against the hog wire netting and then widened on the riverside until the dam is brought to the desired grade and cross section.

4. MUD BOX

After the sandbags in the trestle cut off the free flow and as soon as the backwater will permit, the mud box can be completed in the following order:

- Clear and grub the base, removing all debris.

- Nail a 2-inch by 6-inch stringer along the inside of the landside row of posts just above the ground.

- One-quarter inch wire strand braces are placed at each bent as shown on the plan.

- 12-inch sheeting is driven along the inside of the wall and nailed to the stringers.

- Earth is dumped and tamped into the box until it slopes from the crest of the sack dam to the top edge of the mud box wall.

H. SUDDEN DRAW DOWN

In the event of a sudden draw down failure, loading the toe of the levee similar to the techniques described for through-seepage control can be used. If under water placement becomes a problem, a temporary earth-filled setback levee may be the only solution.

I. BURROWING ANIMALS

There are generally two methods used to control levee failure caused by water flowing through holes in the levee created by burrowing animals:

- Ring the landside opening with sacks the same as for a sand boil

- Plug the opening on the riverside with sandbags or plastic sheeting.

When a leaking burrow is first observed, effort should be made to first stop the flow from the riverside by spreading a tarpaulin or plastic sheeting on the riverside slope and weighting it down with sandbags. A single sack over the riverside opening of the burrow may stop the burrow from leaking if the opening can be found, but the tarpaulin or plastic sheeting has the advantage of covering a larger area since the intake opening might not necessarily be exactly opposite the discharge opening. The tarpaulin or plastic sheet would probably be more impervious than a sandbag and would therefore provide a better seal.

If the burrow hole is high up on the landside slope with minimal hydraulic head, sacks tamped directly into the outlet will effectively stop the flow. It would be necessary to cut a small notch or bench at the opening to seat the sacks into place.

Landside treatment, which may be required if the riverside opening cannot immediately be stopped, is to build a sack ring similar to a boil ring around the landside opening with a sufficient base width to support a ring to a height sufficient to stop the flow of water. This ring differs from a boil ring in that it is required to stop the flow of water. The time, material, and labor required for a ring emphasizes the importance of first attempting to stop the flow from the riverside of the levee structure.

SECTION VI

SANDBAGS, MATERIALS, TOOLS AND EQUIPMENT

A. GENERAL.

Due to the increasing scarcity of labor for flood-fighting duties, it is evident that mechanical means have to be put into use to perform the work previously done by hand. For instance, the large volume of labor necessary for sandbagging operations can be substantially reduced by the use of small trenching machines which dig the material and discharge it to the side; or by using a backhoe or small dragline and a combination hopper-belt conveyor, sandbags can be filled directly on trucks, with the use of very little labor. The utilization of electric saws and air hammers, etc., in the mass production of such articles as cribs and board sections of movable wave-wash protection result in a great savings in labor and also expedites the work.

B. LUMBER

When available, rough, common pine lumber is the most suitable structural material for use in high-water construction. Rough lumber of all structural grades is cut to full size, approximately one-quarter inch being removed from each dimension in dressing. Therefore, rough lumber has greater strength than dressed lumber of the same theoretical dimensions, and should be used whenever possible. Rough lumber is also ordinarily cheaper in cost than dressed lumber.

The principal consideration in obtaining lumber, as well as all other materials for use in high-water construction, is its availability. That which can be placed on the site of operations, in the desired quantity, in the least possible time, is that which should be used.

C. SANDBAGS (SACKS/BAGS)

Sacks or bags filled with earth/material (sandbags) can be used in almost every phase of emergency high-water protection work. Inasmuch as the use of sacks is expensive, from the standpoint both of original cost and cost of filling and handling sandbags, discretion should be exercised so that their use is kept to a minimum. Loose earth, confined between boards, as in a mud box, is more economically placed, and is more impervious than is sacked or bagged earth. If conditions are such that earth-fill used for capping or other purposes can take its natural slope of repose, the use of sandbags may be unnecessary. Because of the excessive time required, sandbags should be used only when other means of confining earth are impracticable. Nevertheless, in flood-fighting operations, the value of sandbags lies in the fact that they increase the usefulness of soil, sand, or gravel as an emergency construction material. Sacks or bags filled with soil or aggregate become building units, in a sense, similar to bricks. As such, they can be used in a variety of ways to protect levees or to build structures employed in flood fighting. Sandbags are made of three different types of material:

woven polypropylene, spun-bonded polypropylene and jute burlap. Each type of material provides a particular advantage. However, for overall use in flood fighting operations, sacks or bags made of polypropylene is the most effective and economic compared to those made of jute burlap.

Cement mixers, loaded with sand can be used as a fast and efficient method of filling sand bags, if available.

1. WOVEN POLYPROPYLENE SANDBAGS

The type of sandbag most widely used is made of woven polypropylene fabric. Polypropylene fabric is available in various grades having different properties and uses. Consequently, care should be exercised in acquiring bags made from this or similar fabrics. Therefore, individuals responsible for determining the specific use to which sandbags may be subjected as well as those responsible for purchasing the bags should become familiar with the basic terminology used in the bag manufacturing industry. Some of the more commonly used terms are presented and briefly explained in the succeeding paragraphs.

In the bag and sack manufacturing industry woven polypropylene bags made of I-96 fabric or its equal are known as "fertilizer bags." Bags made of I-212-6AS fabric or its equal is commonly known as “rice bags” and is used for shipping rice. Rice bags come in two sizes: 50 lb. bags and 100 lb. bags. Of the two, the 100 lb. size bags, either the "fertilizer" or "rice" bag, are the most useful and economic in sandbagging operations. These bags generally measure approximately 19- ½ inch by 35- ½ inches when flat and unfilled and weigh approximately 228 pounds per 1,000, their dimensions may vary slightly depending on manufacturer.

For the purpose of identification, bags made of I-96 fabric are designated by a "black selvage marker" which is simply one black strand of material in the weave around the edge of the material located at the top of the bag. The I-121-6AS fabric is identified by a "black and yellow selvage marker;" i.e., two strand, one black and one yellow. These or similar identification markings will, in most cases, appear on bags made with selvage tops. Selvage is defined as the edge of woven fabric finished to prevent raveling.

Colors of selvage markers will vary according to manufacturer and type of fabric. I-96 fabric conforms to specification requirements of the US Agency for International Development and I-212-6AS fabric conforms to specification requirements of the US Department of Agriculture. Both of these products have, for practical purposes, essentially the same properties. They differ basically only in color and in that the 1-96 fabric has an ultra violet light resistance (known as U.V. Resistance) of 70 percent strength retention after 400 hours of exposure while the I-121-6AS has the same strength retention after 200 hours of exposure. New polypropylene fabrics on the market today provide ultra violet resistance of up to 1200 hours.

Other terminology that one should be familiar with concerning the fabric or yarn with which bags are made are terms such as "slide angle." Slide angle gives an indication of its anti-skid or anti-slip characteristics. The larger the slide angle the less the bags will tend to slide or slip when stacked. A slide angle of about 30º is desirable as it compares to the anti-skid quality of the I-121-6AS rice bag. The "weight' of a fabric is usually referred to as its weight in ounces per square yard of fabric. "Tensile strength" is important too. A "tensile strength' of 105 lbs. and above provides a good sturdy bag fabric. In woven fabric or yarn, the "yarn count" is also very important. In material such as I-121-6AS or 1-96, "count" refers to the actual number of polypropylene strand contained in one square inch of fabric; i.e., counting the strand in both directions. Yarn count is expressed in terms such as 12x10, 12x11 or 12x9.5 and so on. In general, the higher the two figures, the tighter the weave, hence, less space between strand and as a result, there should be less soil loss through leaching when the sandbag is exposed to current scour or wave-wash.

To provide a prospective buyer with a basis for comparing types of sandbag fabrics, a list giving the specifications most commonly used is presented in Table VII. The list should be useful in acquiring the specified and/or best bag for the best price.

Because they do not rot, polypropylene bags can be filled and stored (under cover from sunlight) prior to use for long periods of time. These bags can also be used for wave-wash protection, but in this type of application under heavy wave-wash activity, it may be necessary to fill the bags with sand or gravel rather than soil in order to avoid above normal loss of material through leaching. Polypropylene bags do not create a fire hazard while in storage, are resistant to deterioration by the effects of sunlight, have an anti-skid surface and are light in weight. New "misprints" are bags that have been rejected due to an error in the printing of the brand name or advertisement. The quality of the bag is obviously not affected. New "misprint" bags generally cost less than new manufactured bags. A word of caution, “loused" polypropylene bags should not be used under any circumstances except as a last resort because of fabric stretching which can result in excessive loss of fill material if the sandbags are exposed to current scour or wave-wash. In summary, the advantages of using polypropylene bags in flood-fighting operations are numerous. As such, if time permits and given a choice, emergency operation personnel in charge of requisitioning bags should consider the data as presented herein to acquire the type of bag most advantageous to their needs.

Bags or sacks made of spun-bonded polypropylene, such as TYPAR or equal, are made of the same basic material and have similar characteristics as those made of woven polypropylene. However, spun-bonded polypropylene bags are superior in preventing loss of soil through leaching and have shown evidence of a greater bursting strength. The greater bursting strength exhibited by this bag has been partially credited to the way the bag was manufactured using a specially sewn bottom seam and a welded hot melt center seam. However, it must be noted that TYPAR bags, put together entirely by sewing of both the bottom and side or center seams, gave "poor" results during the "drop tests" conducted, but those manufactured in the proper manner gave excellent results. Because these bags are made of two bonded layers of spun polypropylene and because the spaces between the individual fibers of each layer of material are so small, only the very finest particles of soil can pass through, thereby reducing loss of soil aggregate. Because of the relative newness of this type of sandbag, these bags may not be readily available on the open market. Another advantage provided by this bag is that after the first shovel-full of soil is placed into the bag, the bag will remain opened and stand upright so that it takes only one person to fill. The slight stiffness of the spun-bonded material keeps the bag opened and, therefore, the use of sack racks or a second person to hold the bag open while being filled is not required. These bags weigh approximately 256 pounds per 1,000.

2. JUTE BURLAP SANDBAGS

Sacks or bags made of no less than 10-ounce jute burlap material and to approximately the same dimensions as the woven polypropylene bags are also used for flood-fighting purposes. These bags weigh approximately 660 pounds per 1,000. Experience has shown that jute burlap bags will deteriorate by rotting within 2 to 3 weeks. In addition, when the sandbag is exposed to active wave-wash and current scour, fine-grained material will filter out or leach from the bag at a rate depending upon the tightness of the weave of the burlap. Thus, the quality of the burlap can be a prime factor in causing material loss that, in turn, can adversely affect the usefulness of the sandbag. Therefore, as a general rule, if use of burlap bags is anticipated, where possible they should be restricted to levee topping projects, use in short duration emergency situations of 3 weeks or less, or where eventual removal of the sandbag is neither necessary nor required since the jute burlap will eventually decompose and become part of the surrounding soil.

3. SOIL LEACHING FROM SANDBAGS

Soil loss through leaching from any type of sandbag of as much as 15 percent to 20 percent over a period of time can be tolerated in most cases. However, soil loss from burlap and woven polypropylene bags can reach unacceptable levels if stretching of the material permanently opens the weave. Experience, under actual emergency conditions as well as in field tests, has shown that when the weave is stretched, the bag can virtually loose all of its soil content in less than 24 hours when it is directly exposed to active wave-wash and current flow. Loss of soil or sand fill from a bag through leaching can vary between different types of sandbags depending upon soil type and particle size, the bag fabric, degree of handling, and amount of exposure to water action. As previously stated, spun-bonded polypropylene bags offer the greatest resistance to loss of soil through leaching compared to woven polypropylene (second) and burlap (last).

4. SACK RACKS

Under circumstances where it is necessary to fill a large number of sacks in a short period of time, sack racks are very useful. A sack rack may be constructed of rough lumber to the approximate dimensions shown in Plate No. 43 in Appendix B. This type of sack rack can be moved rapidly from place to place as the work progresses. A sack rack can also be made by driving three stakes into the ground with the tops above the ground to the approximate height of the sacks as shown on Plate No. 43, Appendix B.

In situations where sandbags are required to be filled to the maximum and they cannot be wire tied, then it may become necessary to sew the bags closed. If large curved steel needles are not readily available for sewing the sacks, suitable needles can be made quickly and easily out of almost any kind of wood. The wooden needle should be about 7 inches long, whittled down to a diameter which will permit passage through the sack material, about 1/2 inch to 3/8 inch, with a large eye cut in one end and a point on the other. Any heavy twine is suitable for sewing the sacks.

5. TRANSPORTATION OF SANDBAGS

On the job site, when motorized equipment cannot be used, sandbags may be transported in wheelbarrows or on men's shoulders. Wheelbarrows are preferable, as two filled sandbags constitute a load for one wheelbarrow that can be handled by one man if smooth-run planks and a suitable grade are provided. When necessary, filled sandbags are transported on men's shoulders, one sack per man, or in handbarrows carried by two men. The handbarrows have the advantage over carriage on the shoulder if the sandbags are to be transported over a relatively long distance.

Under certain situations, consideration should be given to filling bags or sacks offsite and transporting them to the problem area by trucks or perhaps on pads flown to the spot by cargo-type helicopters.

In instances where vehicles must be sent over roads that are impassable due to mud or sand, their safe passage may be provided by the use of a plank road constructed as shown on Plate No. 44, Appendix B. When travel or other satisfactory means of communication cannot be maintained, walkie-talkie type radio or telephone communication should be provided along dangerous stretches of levee.

5.1 PLANK RUNWAYS

Runways for wheelbarrows are usually constructed of 2-inch by 12-inch planks laid diagonally up the levee slope on a grade not steeper than 1 V on 10 H. The planks should be carefully butted or otherwise arranged to provide a smooth path. In placing runways on the landside slope of the levee, care should be taken not to break the sod by driving stakes through it unnecessarily, or to abrade the slope by other means.

In order to avoid driving stakes into the levee slope, a device known as a "hickey" may be made of 2-inch by 4-inch lumber, as shown in Plate No. 45, Appendix B. A "hickey" is placed at each joint of planks, and a support in the middle of the plank, if necessary. If made wide enough, the "hickey" may be laid to suit the slope of the levee, keeping the planks horizontal. This device can be shifted with the runways. A sack partially filled with earth and placed under the low side of the runway will serve the same purpose, but is not as suitable because a runway, thus supported, will become unstable through continued use.

5.2 DOLLY

Posts for high-water capping or wave-wash revetment are driven, usually with post drivers or post mauls. If posts heavier than 2-inch and 4-inch lumber are to be driven, a simple device known as "dolly" or "baby" may be used as a driver. Such a device is made of a 12-inch diameter log, flattened on the bottom, or several pieces of lumber spiked together sufficient to make a cross-sectional end area of about 6 inches by 12 inches. The "dolly" should be about 20 feet long. Three hand bars 2 inches by 4 inches by 6 feet, rounded for handholds, are spiked to one end at intervals of about 3 feet enabling six men to operate the driver. A short length of 2-inch by 4-inch lumber, sharpened to a point, is spiked on each side of the other end to provide a fulcrum around which the "dolly" can pivot when in use. An additional hand bar may also be spiked near the other end to facilitate carrying and to steady the device while in use.

5.3 POST DRIVE

This type of post driver is suitable for a 1-man or 2-man operation depending on the amount of driving. It is a safe tool to work with, particularly in areas where workers are moving in close quarters. However, because of the diameter of the pipe, the driver is limited for use on up to 4-inch by 4-inch rough-cut lumber and up to 6-inch by 6-inch finished lumber. The driver is made from a 2-foot, 6-inch-long section of 6-inch diameter standard pipe, capped at one end and has two handles welded to the sides as shown on Plate No. 46 in Appendix B.

D. GUIDE TO EQUIPMENT AND PERSONNEL REQUIREMENTS

Certain flood-fighting measures, as previously discussed, by nature require substantial amounts of labor and a number of hand tools and equipment. Consequently, to assist field personnel in determining these requirements, five tables giving basic figures are provided at the end of this manual. See Table Nos. I, II, III, IV, and V.

The figures given indicate the type and number of tools, plus the number of personnel required to construct 1,000 linear feet per day of the particular type of structure without the use of modern mechanical or motorized equipment. It should be understood that these tables are to be used only as "maximums" since the introduction of power tools and equipment, labor-saving methods, and the ingenuity of the individual in charge can drastically reduce the given labor figures.

E. HIGH-WATER REPORTS

Complete records should be kept of all high-water operations and a report made on physical conditions necessitating work, the kind of work accomplished, materials and supplies used, number of men employed, and the time required for construction. Such reports should be used as a basis for estimates for future work of a similar nature.

SECTION VII

SAFETY

A. GENERAL.

By nature, several of the high-water emergency construction methods described herein pose a certain degree of danger to personnel and equipment. Furthermore, during flood emergencies, the loss of key personnel or a piece of urgently needed equipment could be much more serious than in normal operations. Therefore, planning, training, mobilization, and operations of flood emergencies should include all basic accident prevention concepts. Safety regulations, safe procedures and methods should be followed to the extent compatible with the situation.

B. SITE SAFETY AND HEALTH PLAN TEMPLETE (SSHP).

It is highly recommended that a Site Safety and Health Plan (SHHP) be developed prior to a flood event for use in a flood event. A sample SSHP is provided as Exhibit No. 3 in Appendix C.

APPENDIX A

TABLE I
TWO-BOARD CAPPING

The following is a list of personnel and equipment required to construct approximately 1,000 linear feet of two-board capping per day. It is presented as a guide only; to be used in situations where modern earthmoving equipment cannot be used or is not available for accomplishing the work.

Personnel

1 Foreman
6 Sub foremen (skilled laborers)
2 Timekeepers
116 Laborers

Tools and Equipment

4 Axes
6 Claw hammers
4 Mauls (post)
110 Shovels (long-handled, round-pointed)
100 Wheelbarrows
1 Chain saw, with 5 gallons of fuel (minimum)
2 Saws (crosscut, hand)
I Saw set tool (hand crosscut)
6 Files (saw)
1 Plow and team
* Lighting equipment

* Lighting equipment is to consist of the following (quantities to be determined at time of mobilization):

Lanterns
High candlepower
Air pressure light, with fuel Generator Sets, with floodlights and fuel

Earth-fill

400 Cubic yards

TABLE II
THREE-BOARD CAPPING

The following is a list of personnel and equipment required to construct approximately 1,000 linear feet of three-board capping per day. It is presented as a guide only; to be used in situations where modern earthmoving equipment cannot be used or is not available for accomplishing the work.

Personnel

I Foreman
6 Sub foreman (skilled laborers)
3 Timekeepers
190 Laborers

Tools and Equipment

4 Axes
8 Claw hammers
4 Mauls (post)
175 Shovels (long-handled, round-pointed)
165 Wheelbarrows
1 Chain saw, with 5 gallons of fuel (minimum)
4 Saws (crosscut, hand)
1 Saw set tool (hand crosscut)
6 Files (saw)
1 Plow and team
* Lighting equipment

* Lighting equipment is to consist of the following (quantities to be determined at time of mobilization):

Lanterns
High candlepower
Air pressure light, with fuel Generator Sets, with floodlights and fuel

Earth-fill

575 Cubic yards

TABLE III

MUD BOX LEVEE, 3 FEET-6 INCHES AVERAGE HEIGHT

The following is a list of personnel and equipment required to construct approximately 1,000 linear feet of mud box levee (3 feet-6 inches average height) per day. It is presented as a guide only; to be used in situations where modern earthmoving equipment cannot be used or is not available for accomplishing the work.

Personnel

2 Foremen
6 Sub foreman (skilled laborers)
4 Timekeepers
210 Laborers

Tools and Equipment

5 Axes
10 Claw hammers
4 Mauls (post)
200 Shovels (long-handled, round-pointed)
180 Wheelbarrows
1 Chain saw, with 5 gallons of fuel (minimum)
4 Saws (crosscut, hand)
1 Saw set tool (hand crosscut)
6 Files (saw)
1 Plow and team
* Lighting equipment

* Lighting equipment is to consist of the following (quantities to be determined at time of mobilization):

Lanterns
High candlepower
Air pressure light, with fuel Generator Sets, with floodlights and fuel

Earth-fill

925 Cubic yards

TABLE IV

VERTICAL BOARD WAVE-WASH REVETMENT

(Height above ground surface approximately 8 feet)

The following is a list of personnel and equipment required to construct approximately 1,000 linear feet of vertical board wave-wash revetment per day. It is presented as, a guide only; to be used in situations where modern earthmoving equipment cannot be used or is not available for accomplishing the work.

Personnel

I Foreman
3 Sub foremen (skilled laborers)
2 Timekeepers
100 Laborers

Tools and Equipment

4 Axes
2 Hatchets
8 Claw hammers
2 Post drivers
4 Mauls (post)
2 Dollies
10 Shovels (long-handled, round-pointed)
1 Chain saw, with 5 gallons of fuel (minimum)
4 Saws (crosscut, hand)
1 Saw set tool (hand crosscut)
* Lighting equipment

* Lighting equipment is to consist of the following (quantities to be determined at time of mobilization):

Lanterns
High candlepower
Air pressure light, with fuel Generator Sets, with floodlights and fuel

TABLE V

HORIZONTAL BOARD WAVE-WASH REVETMENT

(Height above shelf surface, 2.5 feet)

The following is a list of personnel and equipment required to construct approximately 1,000 linear feet of horizontal board wave-wash revetment per day. It is presented as a guide only; to be used in situations where modern earthmoving equipment cannot be used or is not available for accomplishing the work.

Personnel

1 Foreman
3 Sub foremen (skilled laborers)
1 Timekeeper
30 Laborers

Tools and Equipment

4 Axes
10 Claw hammers
2 Post drivers
2 Mauls
I Dolly
2 Shovels (long-handled, round-pointed)
1 Chain saw, with 5 gallons of fuel (minimum)
4 Saws (crosscut, hand)
I Saw set tool (hand crosscut)
6 Files (saw)
2 Skiffs, with outboard motors and 20 gallons of fuel
* Lighting equipment

* Lighting equipment is to consist of the following (quantities to be determined at time of mobilization):

Lanterns
High candlepower
Air pressure light, with fuel Generator Sets, with floodlights and fuel

TABLE VI

SAMPLE SPECIFICATIONS

TYPICAL SANDBAG FABRIC

Following are material specifications for sandbags made from a woven fabric generally acquired by the NOD.

A.	Material:	Polypropolene, type I-121-6AS
B.	Color:	Tan
C.	Selvedges:	2 Tucked; Black/yellow
D.	Tensil Strength:	
	Warp*	105 lbs.
	Fill**	105 lbs.
E.	Ultra Violet Resistance:	70% Strength Retention after 200 hrs
F.	Weight:	2.6 oz/sq. yd.
G.	Slide Angle:	30 degrees
H.	Yarn Count:	12 x IO
I.	Coating:	AS***

* Warp-Strans running in machine direction; i.e., running parallel to selvage marker.

** Fill-Strans running at right angles to selvage marker.

*** Anti skid

APPENDIX B

EMERGENCY LEVEE INSPECTION CHECKLIST

PROJECT:					DATE/TIME:
SPECIFIC ITEM	**YES**	**NO**	**N/A**	**A**	**COMMENTS/NOTES**
1. Access:					
a. Project accessible (General Location)?					
b. Levee ramp and crest accessible and usable?					
c. Landward side of levee accessible?					
2. Levee Embankment:					
a. Any low areas in danger of being overtopped?					
b. Evidence of seepage on landward slope, toe, or around pipes? (e.g., Boils, soft saturated areas, seeps, etc.)					
c. Any indications of slides or sloughs developing (misalignments, cracking, bulging, etc.)?					
d. Any erosion from wave wash, scouring, or overtopping?					
e. Any areas were riprap or revetment work has been displaced?					
f. Whirlpools observed riverward of levee?					
g. Any evidence of bank caving or erosion riverward of the embankment?					
h. Other?					

SHEET 1 OF 3

EMERGENCY LEVEE INSPECTION CHECKLIST

PROJECT:	DATE/TIME:

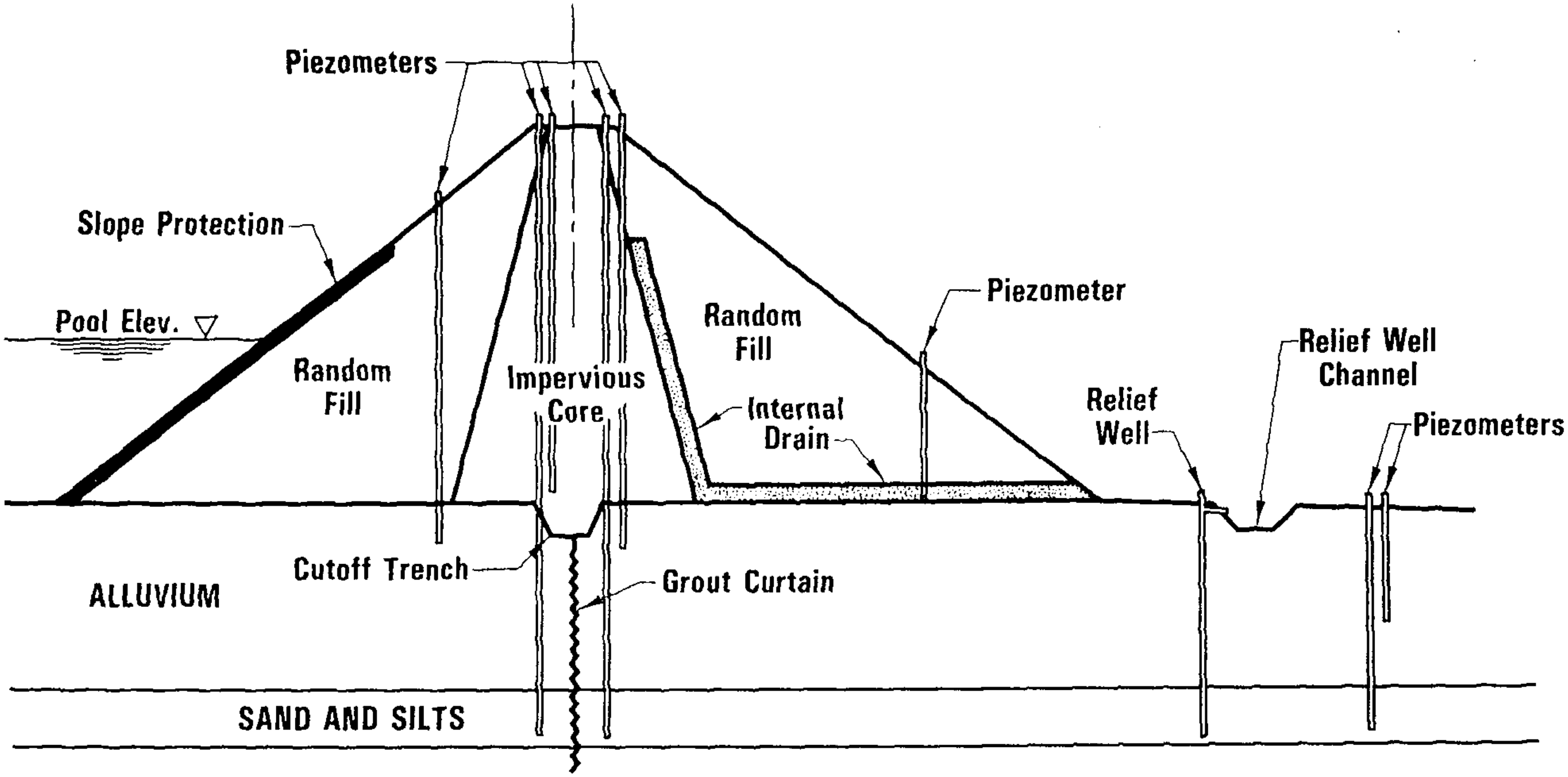
SPECIFIC ITEM	YES	NO	N/A	A	COMMENTS/NOTES
3. Drainage Structures/Floodwalls:					
a. Any evidence of seepage around, through, or adjacent to the structure which might affect its or the embankments stability?					
b. Any signs of settlement that may affect the stability or water-tightness of the structure?					
c. Has the structure deteriorated (e.g. cracked, rusted, etc.) to a point where the structure's stability or water-tightness may be affected?					
d. Any debris or trash accumulated adjacent to inlets, outlets, or other critical areas?					
e. Are flap-gates, slide-gates, or other control structures operational?					
f. Has riprap around structures been displaced?					
g. Other?					
4. Miscellaneous Items:					
a. Are relief wells flowing (record well numbers and flow rates as required)					
b. Are inlet and outlet channels clear of growth and debris?					
c. Are tributary channels clear of debris that might jeopardize the project (e.g., debris at bridges)?					
d. Any obvious signs of distress at pumping plants, closure structures, or other structures?					

SHEET 2 OF 3

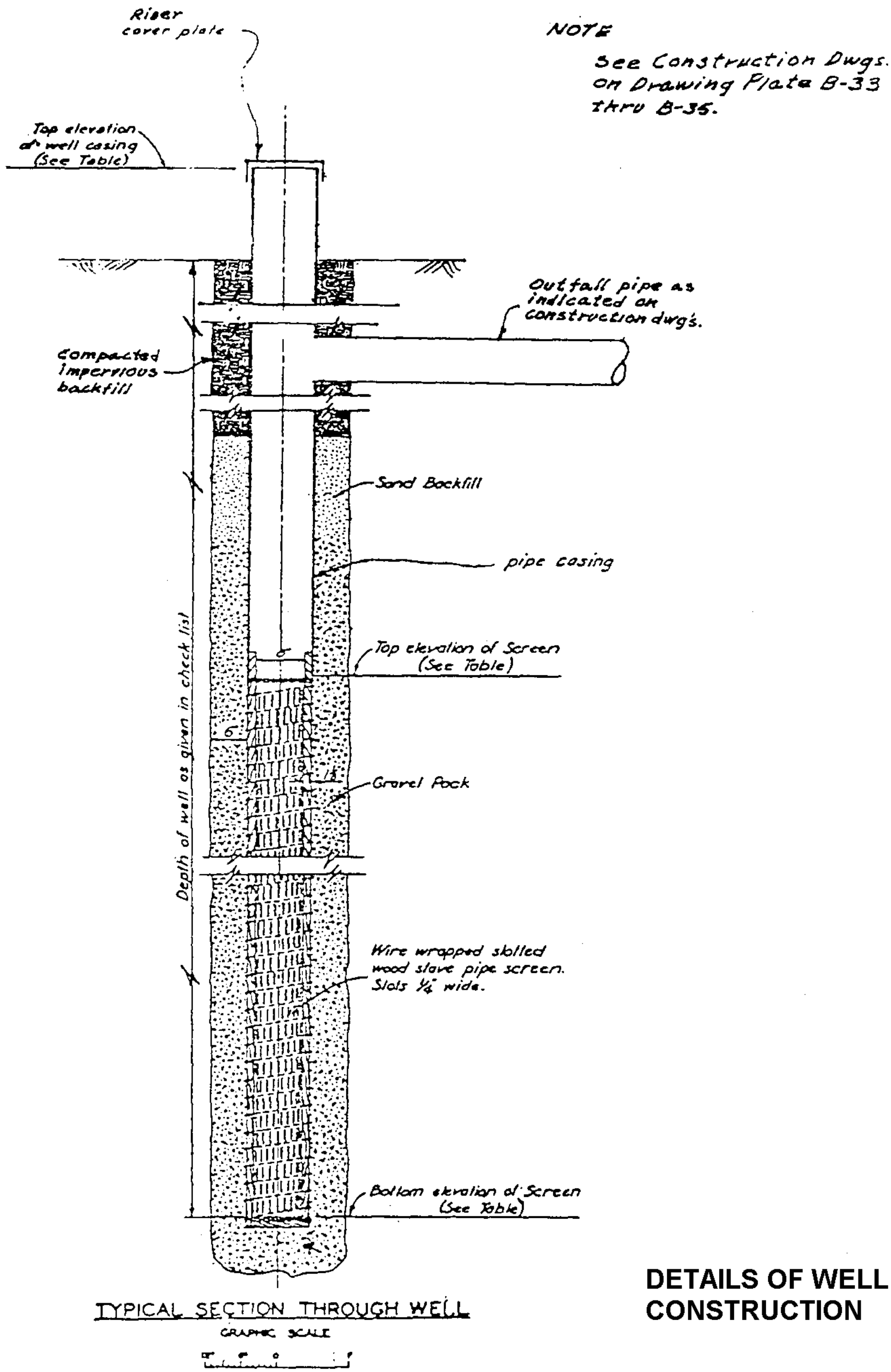
EMERGENCY LEVEE INSPECTION CHECKLIST

PROJECT:					DATE/TIME:
SPECIFIC ITEM	**YES**	**NO**	**N/A**	**A**	**COMMENTS/NOTES**
e. Are closures structures in-place?					
f. Can closure be made promptly if necessary?					
f. Are closure structures leaking or in poor condition?					
g. Are appropriate flood fight materials readily available to implement immediate flood fight operations.					
h. Other?					
WEATHER CONDITIONS:					WATER LEVEL:
NAME & SIGNATURE OF INSPECTOR:					

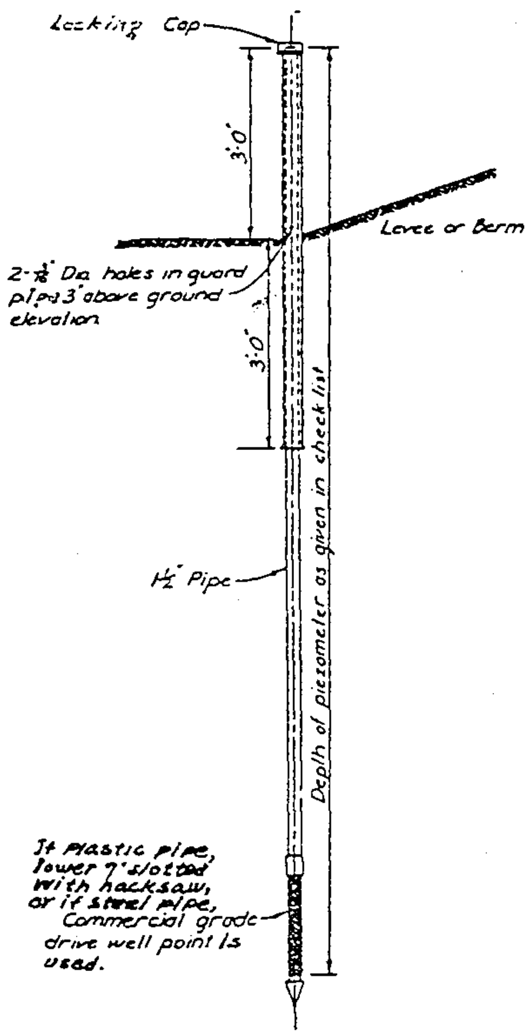
N/A = Not Applicable A = Action Item



EMBANKMENT AND UNDERSEEPAGE CONTROL



DETAILS OF WELL CONSTRUCTION



TYPICAL PIEZOMETER TUBE

GRAPHIC SCALE

DETAILS OF PIEZOMETER TUBE CONSTRUCTION

PLATE NO. 6

EMERGENCY LEVEE INSPECTIONS

PIEZOMETER WATER LEVEL DATA SHEET

PROJECT: **DATE:**

Instrument No.	Depth to Water (Time:)	Depth to Water (Time:)	Depth to Water (Time:)	Notes

INSPECTOR NAME & SIGNATURE:

EMERGENCY LEVEE INSPECTIONS

RELIEF WELL DATA SHEET

PROJECT: **DATE:**

Instrument No.	Depth to Water (Time:)	Flow Rate (Time:)	Depth to Water (Time:)	Flow Rate (Time:)	Notes

INSPECTOR NAME & SIGNATURE:

PLATE NO. 8

EMERGENCY LEVEE INSPECTIONS

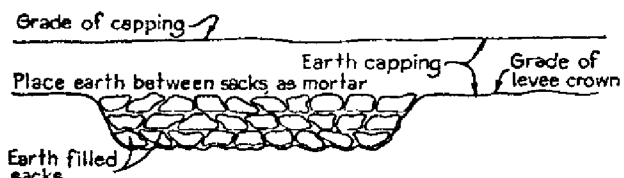
RIVER STAGE DATA SHEET

PROJECT: **DATE:**

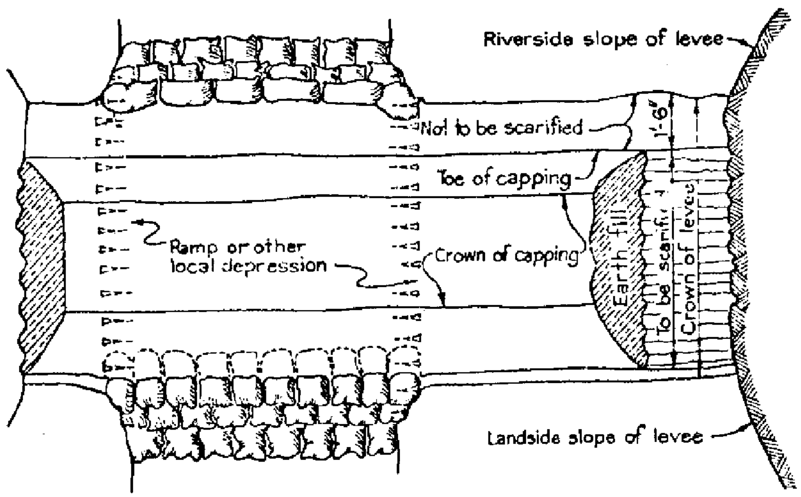
Measurement Location	Time	Notes

INSPECTOR NAME & SIGNATURE:

PLATE NO. 9



ELEVATION



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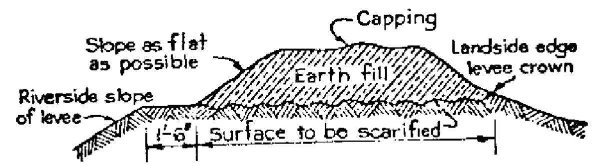
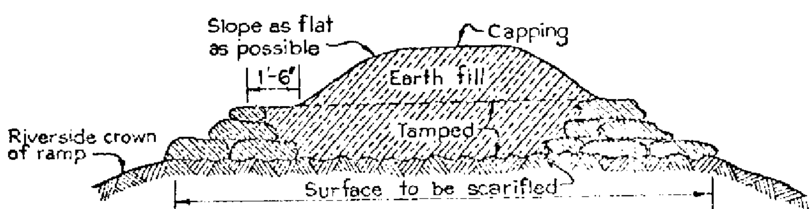


TYPICAL SECTION LEVEE CAPPING

NOTE: This type of capping not to be used on levees with crown less than 10' wide or on levees exposed to wave wash.



TYPICAL SECTION AT RAMP OR OTHER DEPRESSION

EMERGENCY FLOOD FIGHTING

EARTH CAPPING

FOR RAISING DEPRESSIONS AND LEVEE CAPPING

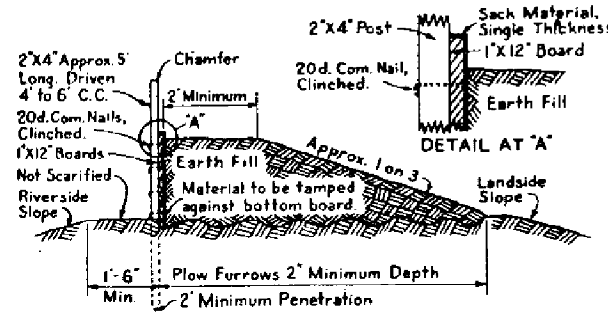
(THIS DESIGN IS ADEQUATE FOR HEIGHTS UP TO 1½')

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

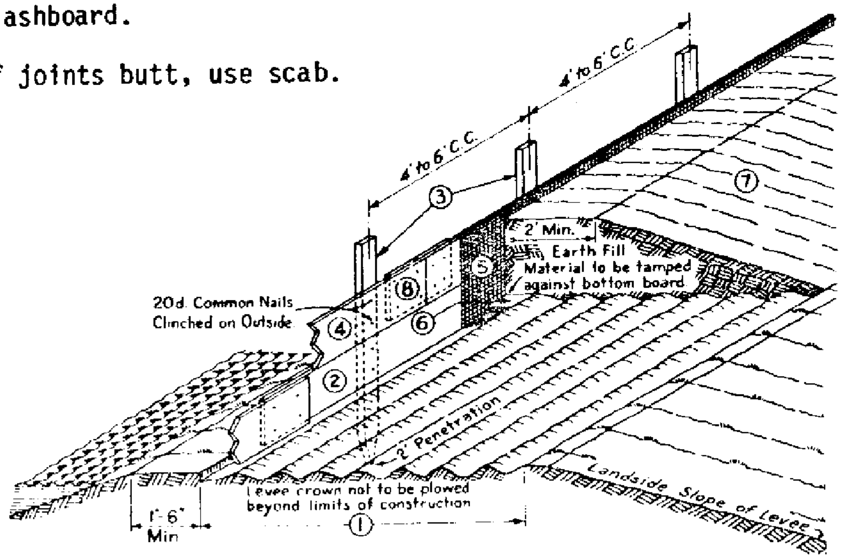
PLATE NO. 10

SEQUENCE OF OPERATIONS

1. Plow crown of levee (2" minimum depth) beginning 1'-6" from riverside edge.
2. Place bottom flashboards on edge of plowed furrow, break joints any place.
3. Place and drive 2"x4" posts from 4' to 6' C.C., nail flashboards to posts.
4. Place top flashboards and nail; break joints any place.
5. Place and nail Visqueen or other material.
6. Refill plowed furrow and tamp on both sides of bottom boards.
7. Place capping material, landside of flashboard.
8. If joints butt, use scab.



SECTION



METHOD OF CONSTRUCTION

TWO BOARD LEVEE CAPPING
BILL OF MATERIALS FOR 1000 LINEAR FEET

201 Posts	2" x 4" x 5'-0"	= 670 bd.ft.
Boards	1" x 12" x 2000 L.F.	= 2000 bd.ft.
		2670 bd.ft.
50 lbs.	20d Common Nails	= 1450 Nails
Visqueen	2-1/2' x 1000'	= 2500 sq.ft.

Actual quantities. No allowance made for waste.

*NOTE: Dimensions based on rough cut lumber.

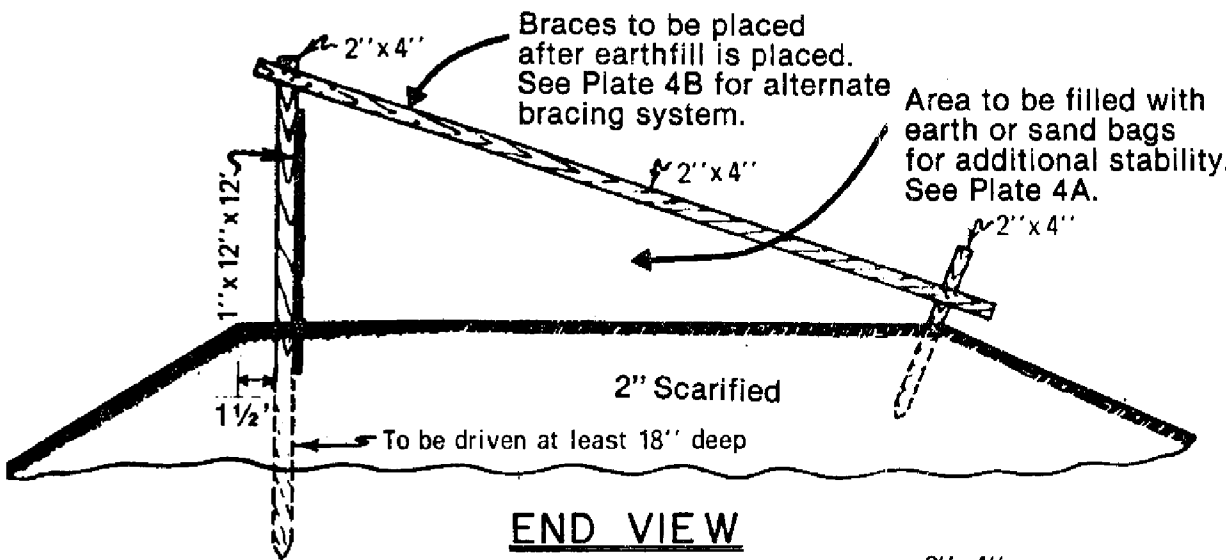
EMERGENCY FLOOD FIGHTING

FLASHBOARD LEVEE CAPPING TWO BOARD TYPE

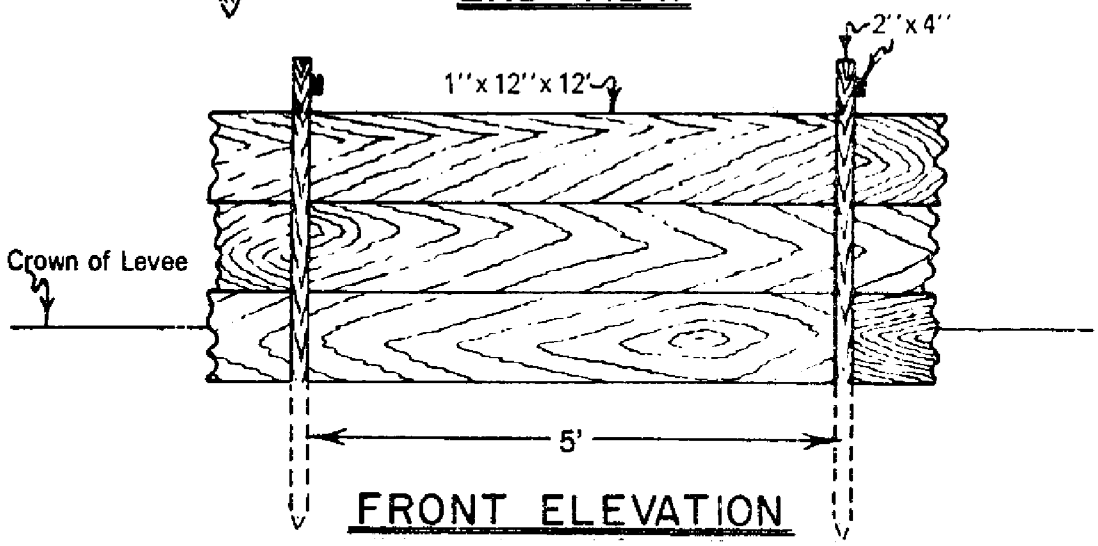
(THIS DESIGN IS ADEQUATE FOR HEIGHTS UP TO 2')

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 12



END VIEW



FRONT ELEVATION

THREE BOARD FLASHBOARD LEVEE CAPPING
BILL OF MATERIAL TO CONSTRUCT 100'

Boards 1"X12"X 300 L.F.	=	300 Bd.Ft.
17 Posts 2"X4"X 6'-0"	=	68 Bd.Ft.
17 Braces 2"X4"X10'-0"	=	114 Bd.Ft.
17 Anchors 2"X4"X2'-0"	=	23 Bd.Ft.
TOTAL		505 Bd.Ft.

Dimensions based on rough cut lumber.
5 lbs. 10d Common Nails

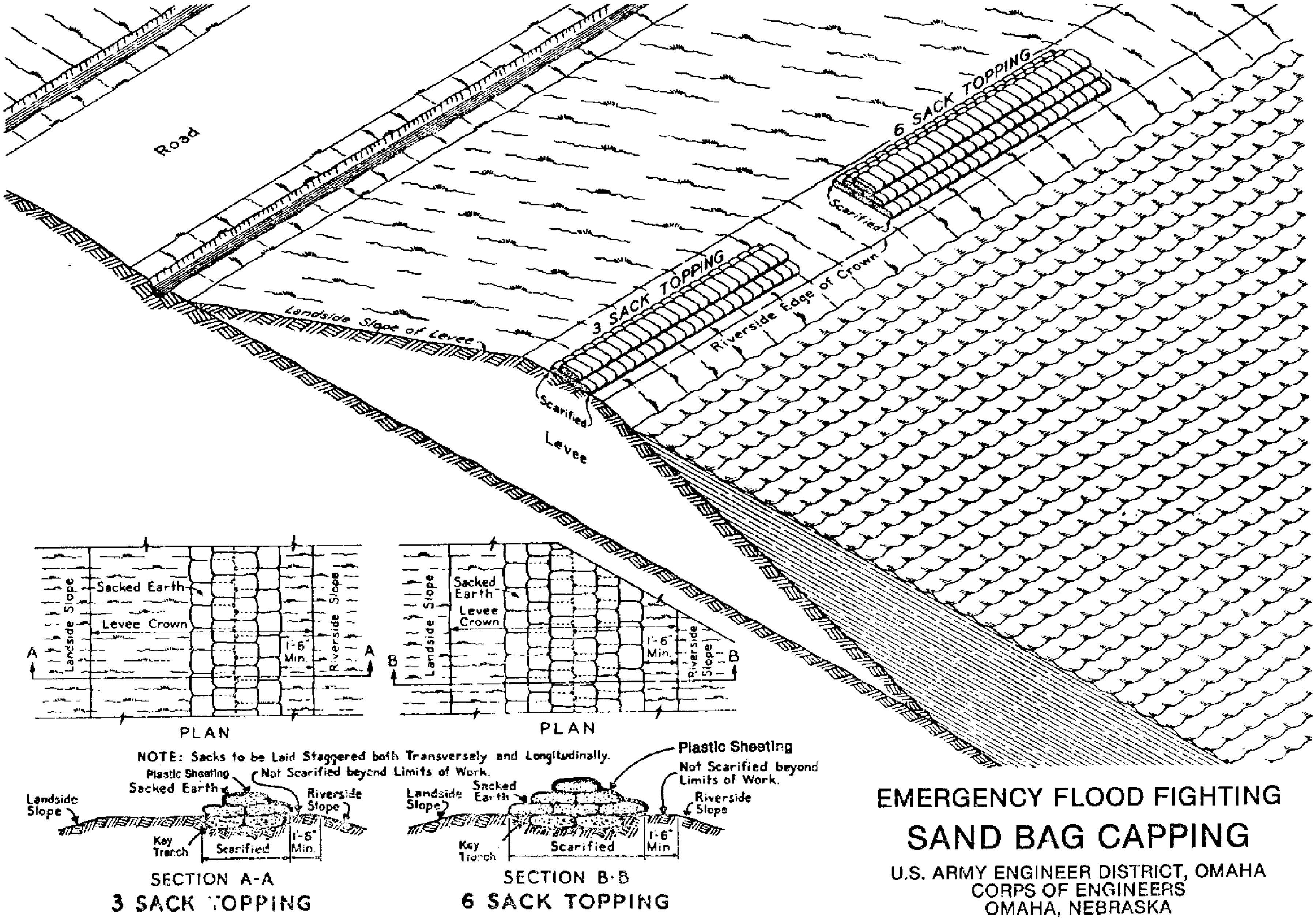
EMERGENCY FLOOD FIGHTING

FLASHBOARD LEVEE CAPPING THREE BOARD TYPE

(THIS DESIGN IS ADEQUATE FOR HEIGHTS UP TO 3')

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 13

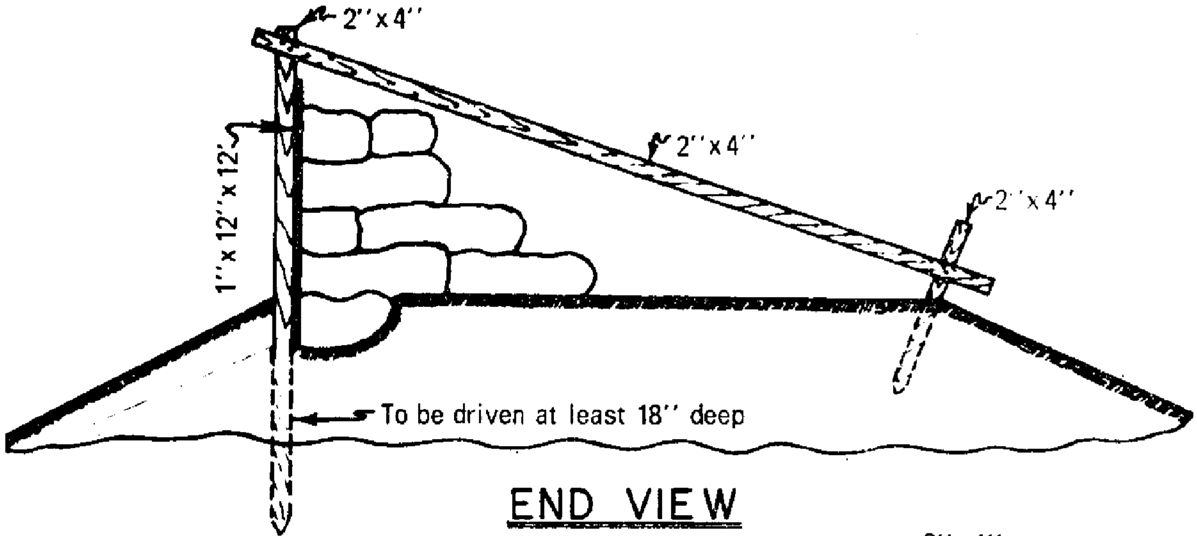


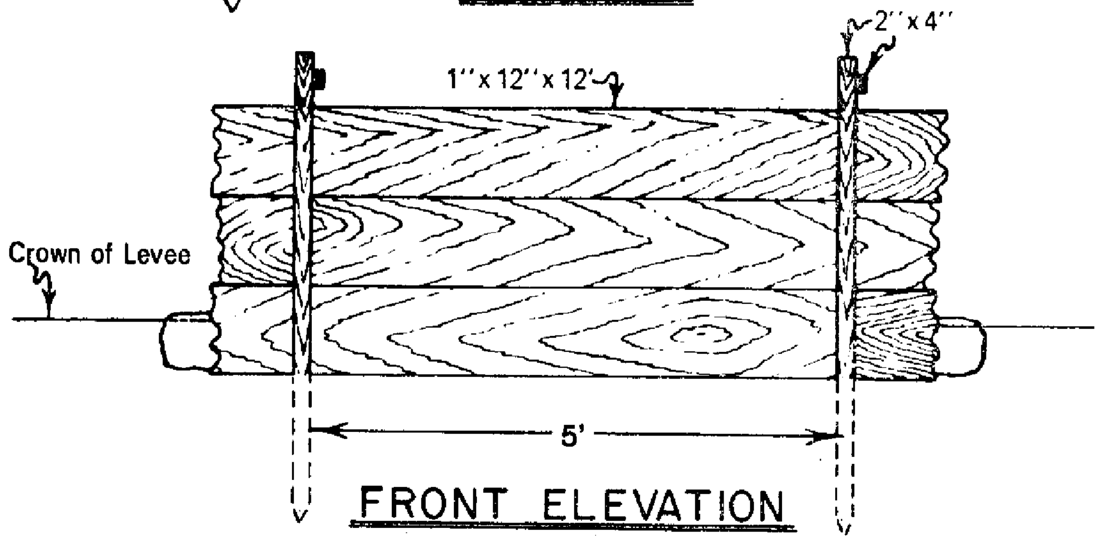
EMERGENCY FLOOD FIGHTING

SAND BAG CAPPING

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 11





THREE BOARD LUMBER AND SACK TOPPING
BILL OF MATERIAL TO CONSTRUCT 100'

Boards	1"X12"X 300 L.F.	=	300 Bd.Ft.
17 Posts	2"X4"X 6'-0"	=	68 Bd.Ft.
17 Braces	2"X4"X10'-0"	=	114 Bd.Ft.
17 Anchors	2"X4"X2'-0"	=	23 Bd.Ft.
	TOTAL		505 Bd.Ft.

Dimensions based on rough cut lumber.
5 lbs. 10d Common Nails
6 - 8 bags/L.F.
800 bags

EMERGENCY FLOOD FIGHTING

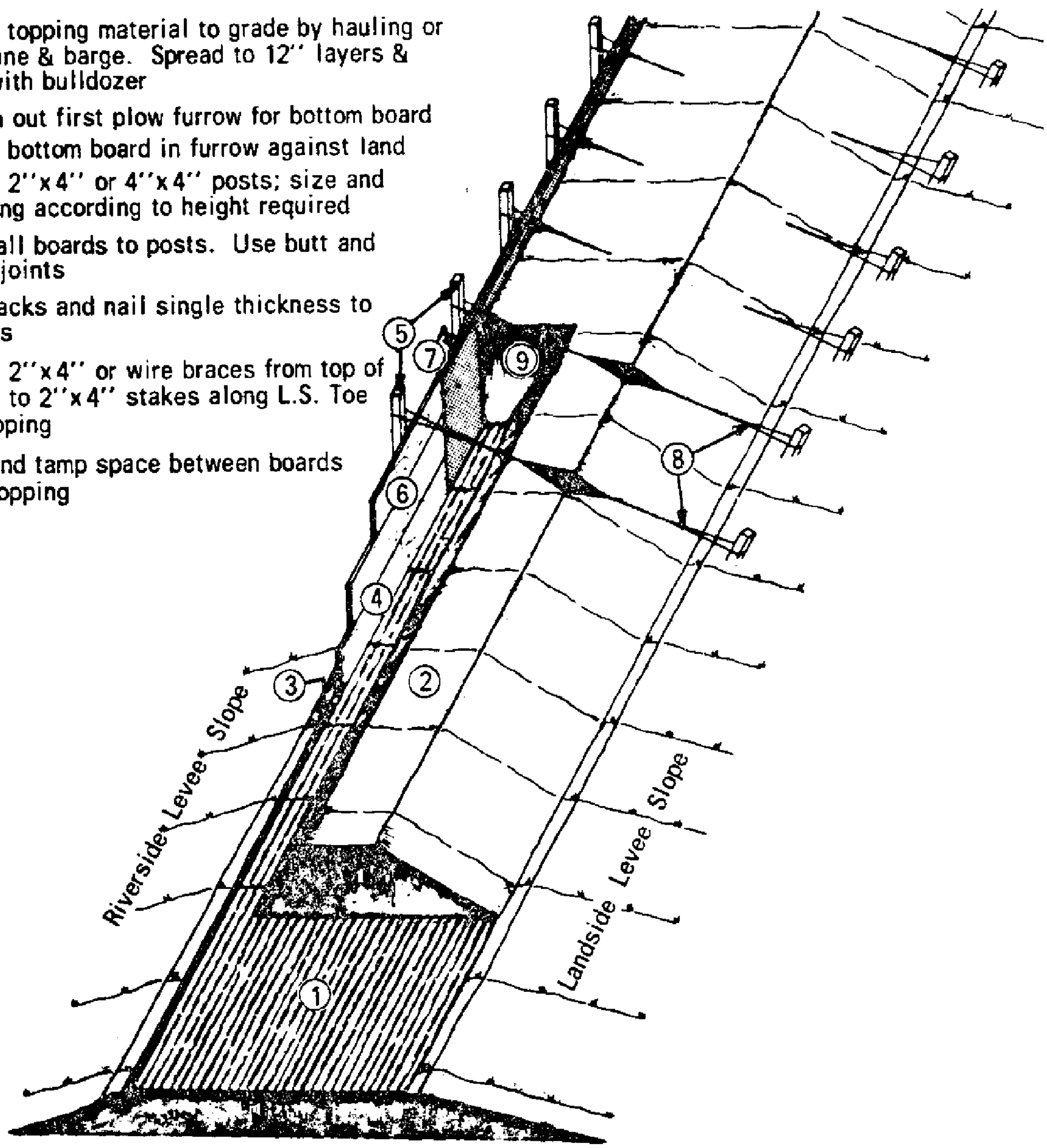
LUMBER AND SACK TOPPING

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 14

SEQUENCE OF OPERATIONS

1. Plow crown of levee
2. Place topping material to grade by hauling or dragline & barge. Spread to 12" layers & roll with bulldozer
3. Clean out first plow furrow for bottom board
4. Place bottom board in furrow against land
5. Drive 2"x4" or 4"x4" posts; size and spacing according to height required
6. Nail all boards to posts. Use butt and scab joints
7. Rip sacks and nail single thickness to boards
8. Place 2"x4" or wire braces from top of posts to 2"x4" stakes along L.S. Toe of topping
9. Fill and tamp space between boards and topping



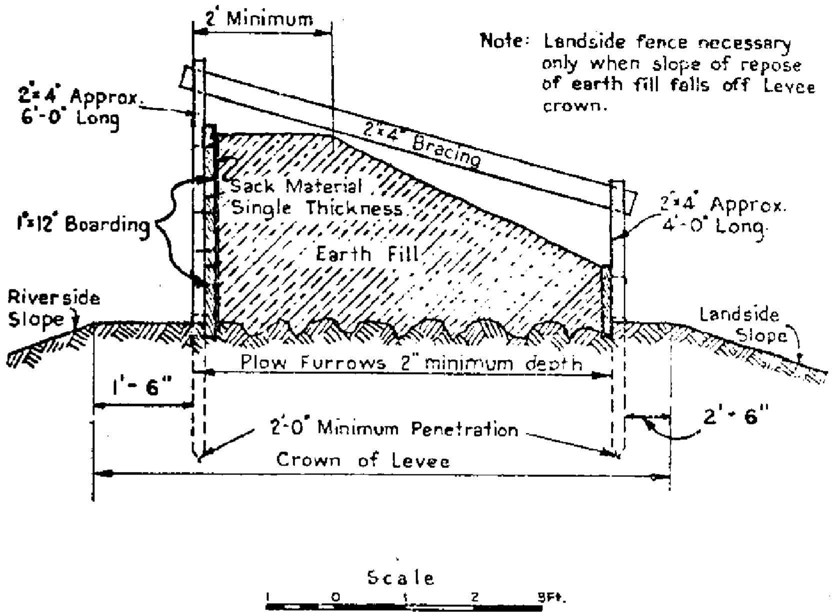
MATERIAL REQ. FOR 100' X 3'H

Posts - 17 pc's 2"x4"x12' Spaced 3' = 136 b.f.
or 13 pc's 4"x4"x12' Spaced 4' = 208 b.f.
Boards - 300 FBM 1"x12" x Any Length = 300 b.f.
3' Brace Stakes - 8 pc's 2"x4"x12' = 64 b.f.
300 Sq.Ft. Visqueen
5 lbs. 16d Common Nails
Braces - 1000 ft. (121 lbs.) 1/4" Strand

EMERGENCY FLOOD FIGHTING

BOARD & EARTH TOPPING MECHANICAL METHOD

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA



BILL OF MATERIALS FOR 1000 LINEAR FEET
OF THREE BOARD CAPPING FOR NARROW
CROWN LEVEE (MAX. 3' HIGH)

201 Posts	2"X4"	X 6'-0"	=	804	Bd.Ft.
201 Posts	2"X4"	X 4'-0"	=	536	Bd.Ft.
*201 Braces	2"X4"	X 14"=0"	=	943	Bd.Ft.
Boards	1"X12"	X 2000 L.F.	=	4000	Bd.Ft.

Dimensions based on rough cut lumber

50 lbs. 8d. Common Nails
30 lbs. 20d. Common Nails

*NOTE: Should get two braces from each board.

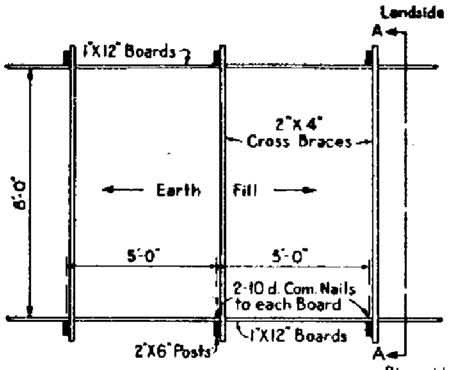
EMERGENCY FLOOD FIGHTING

FLASHBOARD LEVEE CAPPING
THREE BOARD TYPE

(THIS DESIGN IS ADEQUATE FOR HEIGHTS UP TO 3')

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 16



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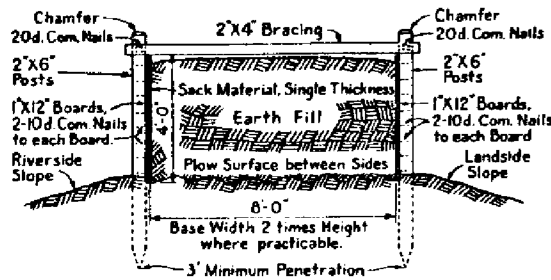


SECTION A-A

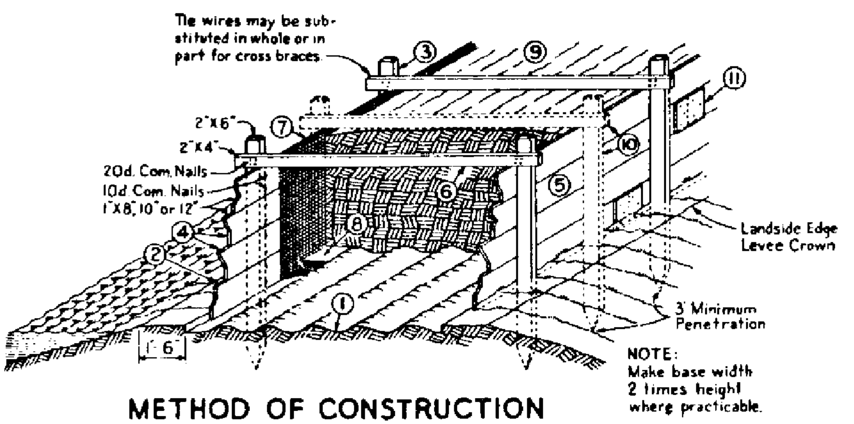
MUD BOX LEVEE CAPPING — 4 FEET HIGH
BILL OF MATERIALS FOR 1000 LINEAR FEET

402 Posts	2"X6"X8'-0"	=	3216 Bd. Ft.
201 Ties	2"X4"X10'-0"	=	1340 Bd. Ft.
Boards	1"X12"X8000 L.F.	=	8000 Bd. Ft.
	Total		12,556 Bd. Ft.

100 Lbs. 10d. Common Nails
80 Lbs. 20d. Common Nails
1700 Sacks
Actual quantities. No allowance made for waste.

4500 Sq.Ft. Visqueen 2-1/2' X 1000'

*NOTE: Dimensions based on rough cut lumber.



METHOD OF CONSTRUCTION

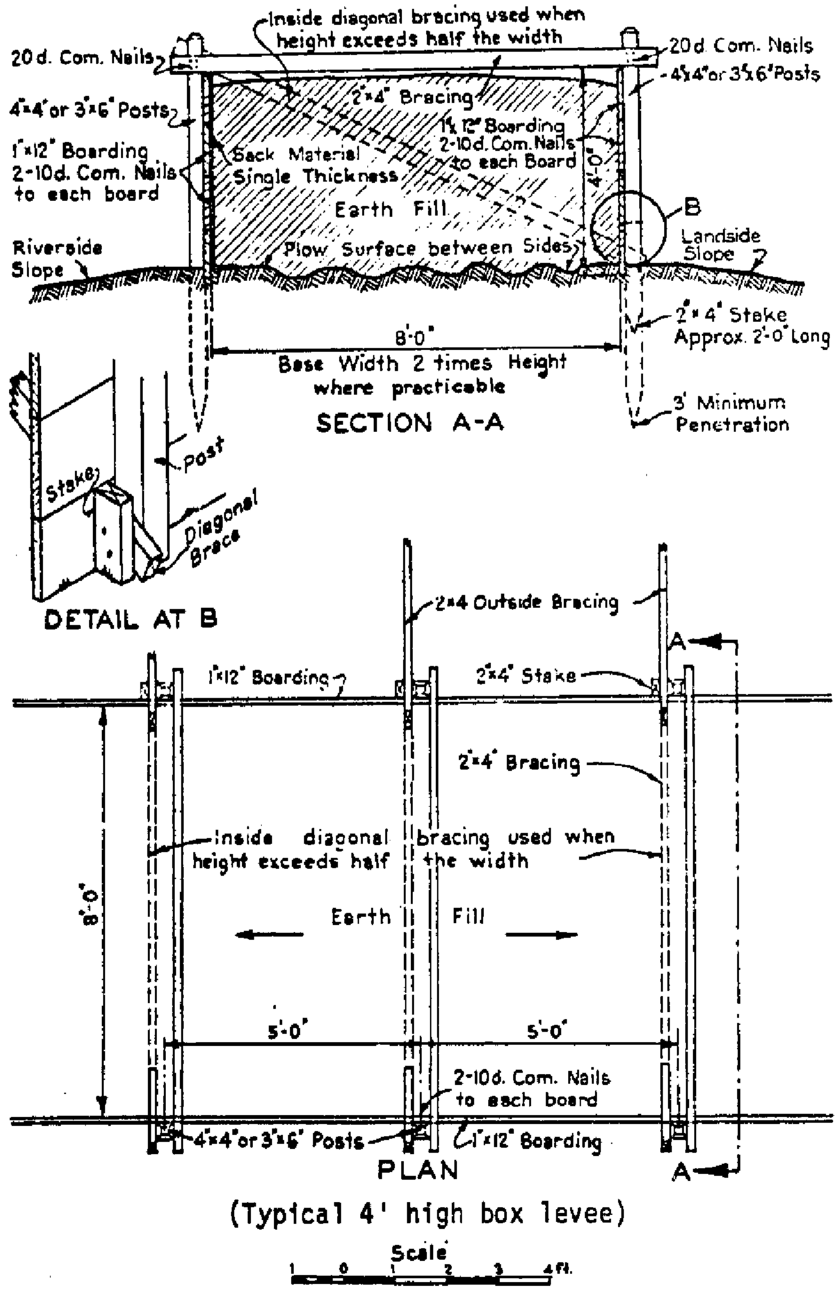
SEQUENCE OF OPERATIONS

1. Plow crown of levee (2" minimum depth) beginning 1'-6" from riverside edge.
2. Place bottom board.
3. Place and drive posts at 4' to 6' C.C. so ends of boards will meet on posts.
4. Place additional boards and nail.
5. Construct landside fence.
6. Brace fences together.
7. Place and nail sack material.
8. Refill furrow and tamp on both sides of bottom board.
9. Place earth fill between fences.
10. Drive and brace additional posts if earth fill exceeds 3 ft. in height.
11. Break joints any place. If joints butt, use scab.

EMERGENCY FLOOD FIGHTING
MUD BOX LEVEE CAPPING
(FOR CAPPING IN EXCESS OF 3' IN HEIGHT OF NARROW CROWN LEVEE CAPPING)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 17



(Typical 4' high box levee)

BILL OF MATERIALS FOR 1000 LINEAR FEET
FOR BOX LEVEE WITH DIAGONAL BRACING

201 Stakes 2"X4"X2'-0"	= 268 Bd.Ft.
201 Diagonal Braces 2"X4"X10'	= 1340 Bd.Ft.
402 Posts 4"X4"X8'	= 4288 Bd.Ft.
201 Bracing 2"X4"X8'	= 1072 Bd.Ft.
Boarding 1"X12"X8000'	= 8000 Bd.Ft.
	14,968 Bd.Ft.

Dimensions based on rough cut lumber.

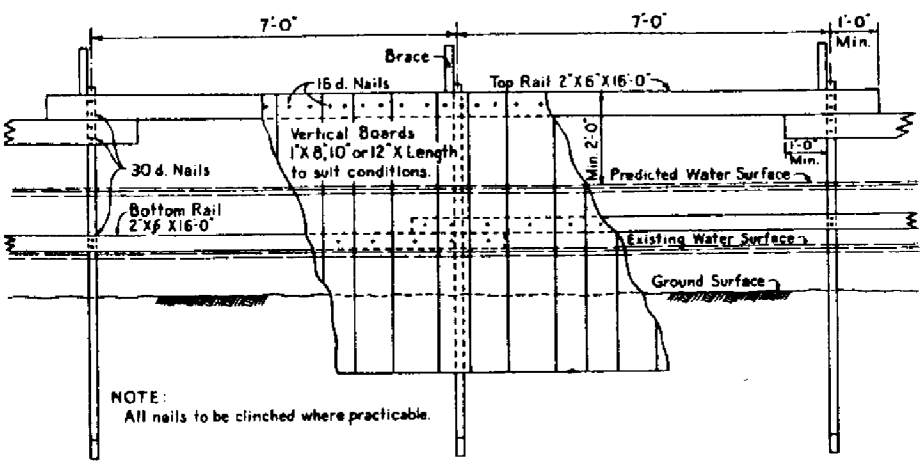
60 lb. 20d. Common Nails
60 lb. 10d. Common Nails

EMERGENCY FLOOD FIGHTING

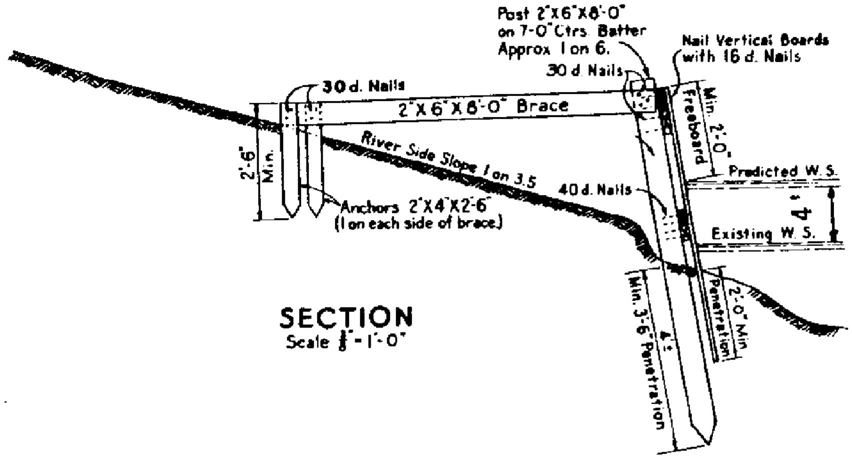
MUD BOX LEVEE WITH DIAGONAL BRACING

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 18



ELEVATION
Scale $\frac{3}{8}$"=1'-0"



SECTION
Scale $\frac{3}{8}$"-1'-0"

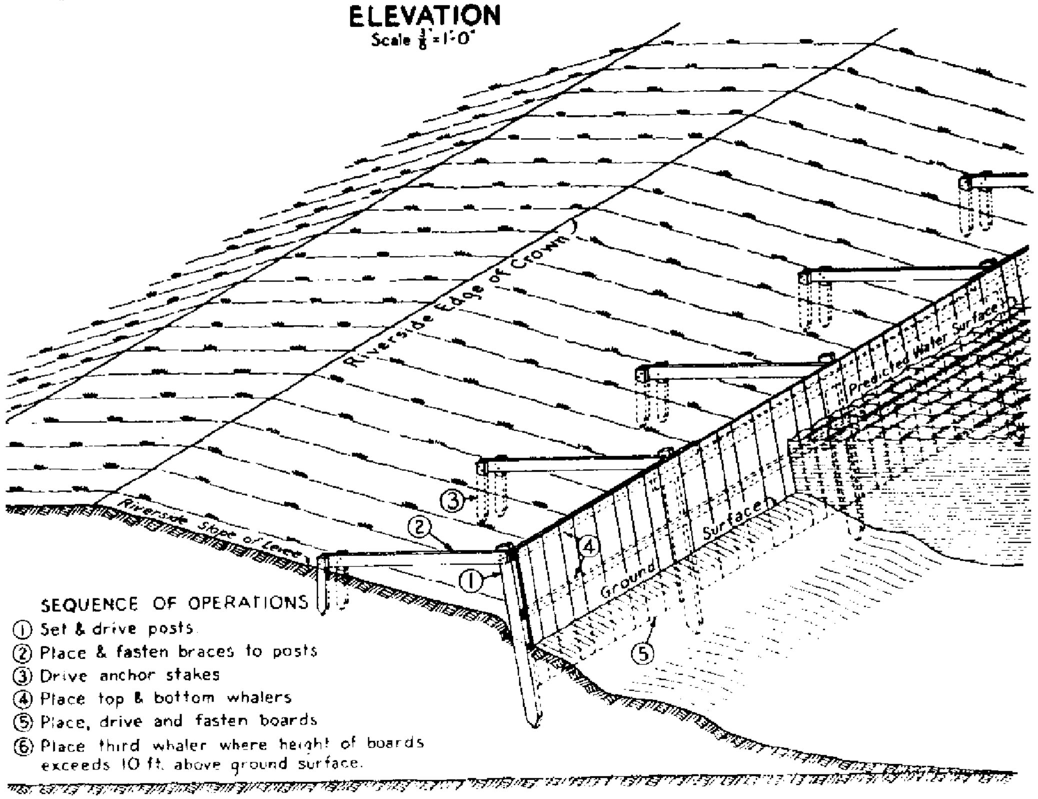
BILL OF MATERIALS FOR 100 LINEAR FEET OF REVETMENT WITH BRACES ON 7'-0" CENTERS
(Using Boards 6 Feet Long)

14.5	Posts	2"X6"X8'-0"	= 116 Bd. Ft.
14.5	Braces	2"X6"X8'-0"	= 116 Bd. Ft.
29	Anchors	2"X4"X2'-6"	= 49 Bd. Ft.
7	Rails	2"X6"X16'-0"	= 112 Bd. Ft.
7	Rails	2"X4"X16'-0"	= 75 Bd. Ft.
	Vertical Boards	1"X8", 10" or 12"X6'-0"	= 600 Bd. Ft.
		Total	1068 Bd. Ft. (Net)

6 Lbs. 30d. Common Nails
6 Lbs. 16d. Common Nails
Actual quantities. No allowance made for waste.

Dimensions based on rough cut lumber

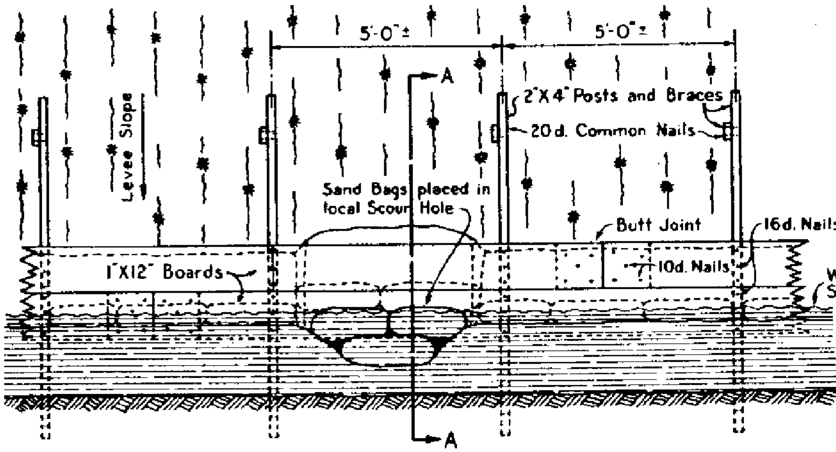
NOTE: When horizontal brace span is greater than 10' diagonal bracing and strongback is required. (Plate 7A)



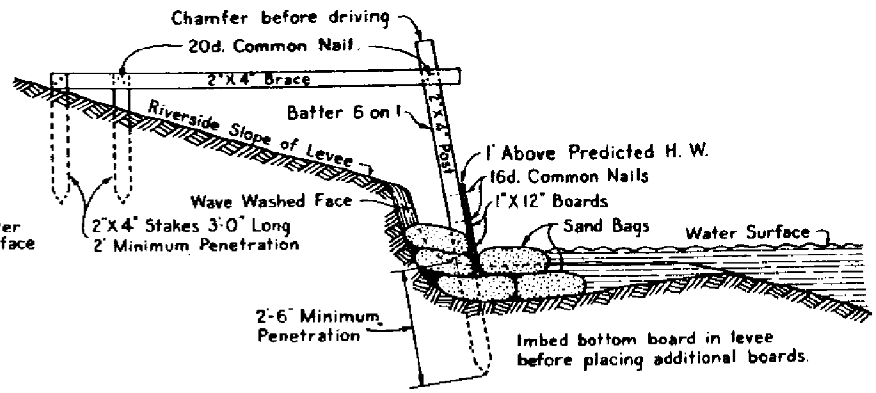
SEQUENCE OF OPERATIONS
① Set & drive posts
② Place & fasten braces to posts
③ Drive anchor stakes
④ Place top & bottom whalers
⑤ Place, drive and fasten boards
⑥ Place third whaler where height of boards exceeds 10 ft. above ground surface.

EMERGENCY FLOOD FIGHTING
VERTICAL BOARD REVETMENT

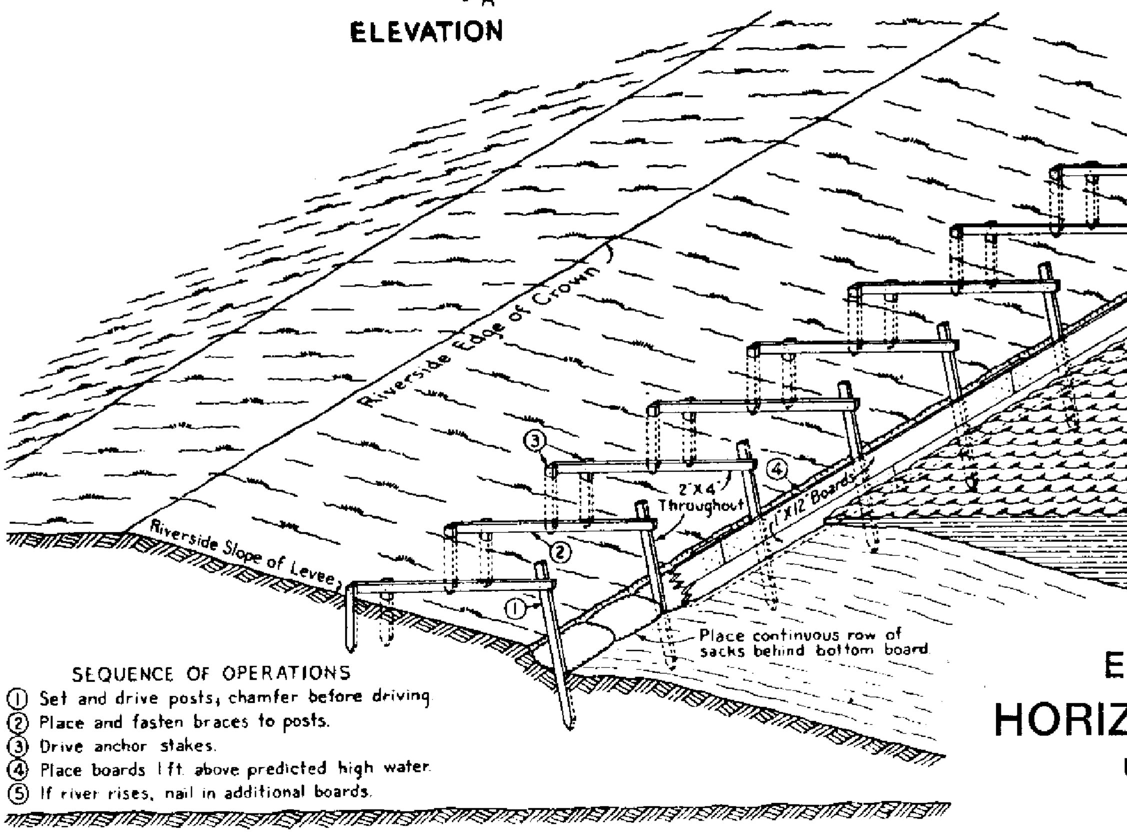
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA



ELEVATION



SECTION A-A



SEQUENCE OF OPERATIONS

1. Set and drive posts; chamfer before driving.
2. Place and fasten braces to posts.
3. Drive anchor stakes.
4. Place boards 1 ft. above predicted high water.
5. If river rises, nail in additional boards.

BILL OF MATERIALS FOR 100 LINEAR FEET OF REVETMENT WITH BRACES ON 5'-0" CENTERS
(Using Posts 8 Feet Long) *

21 Posts	2"X 4"X 8'-0"	= 112 Bd. Ft.
21 Braces	2"X 4"X 9'-0"	= 126 Bd. Ft.
42 Anchors	2"X 4"X 3'-0"	= 84 Bd. Ft.
Horizontal Boards	1"X12"X240 Lin. Ft.	= 240 Bd. Ft.
	* Total	562 Bd. Ft.

3 Lbs. 10d. Common Nails
3 Lbs. 16d. Common Nails
5 Lbs. 20d. Common Nails

Actual quantities. No allowance made for waste.

NOTE:
Use this method only in localities subject to light attack. Use vertical board fence for all other cases.

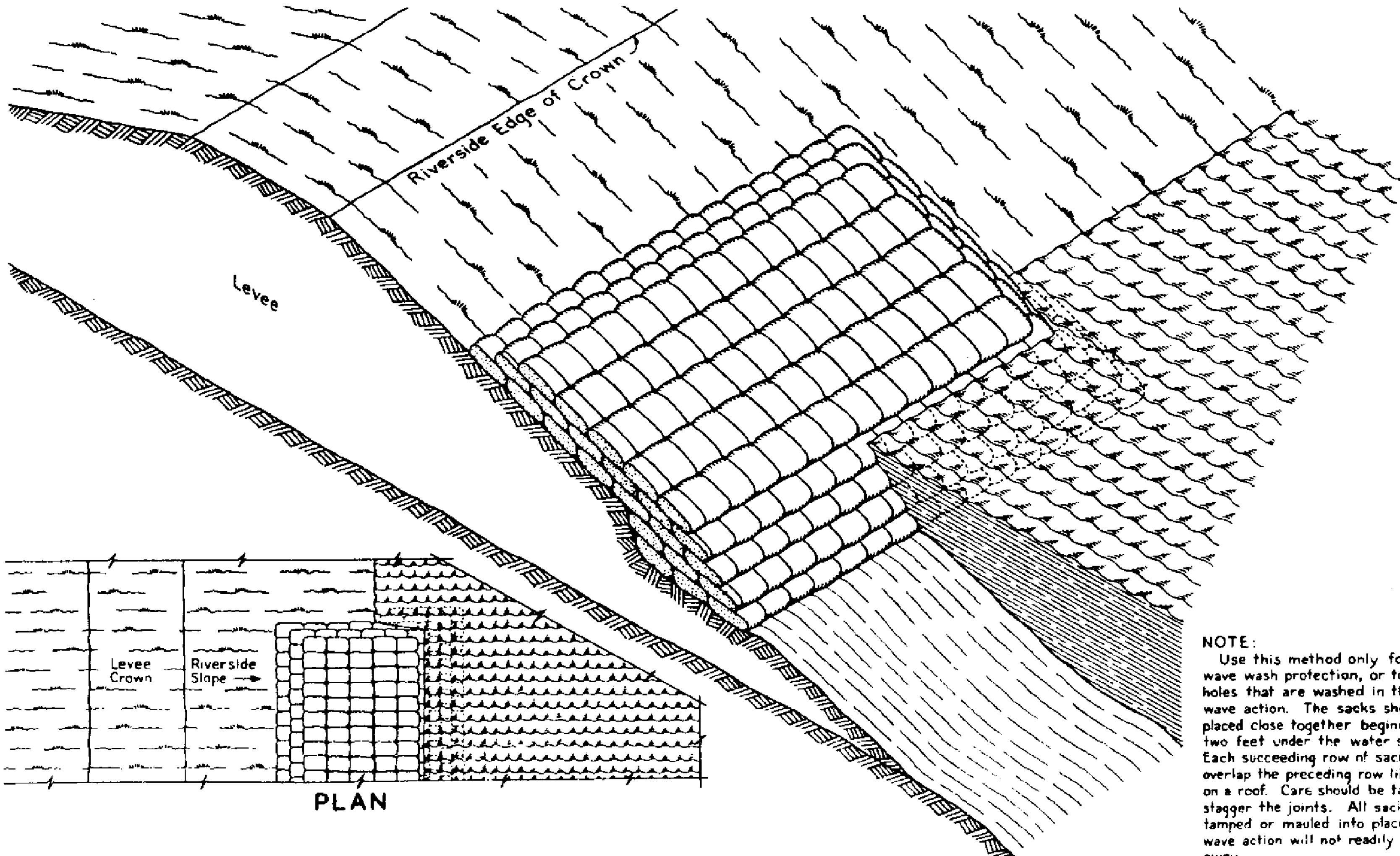
*Dimensions based on rough cut lumber

EMERGENCY FLOOD FIGHTING

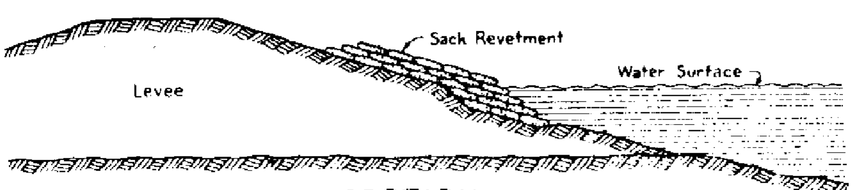
HORIZONTAL BOARD REVETMENT

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 20



PLAN



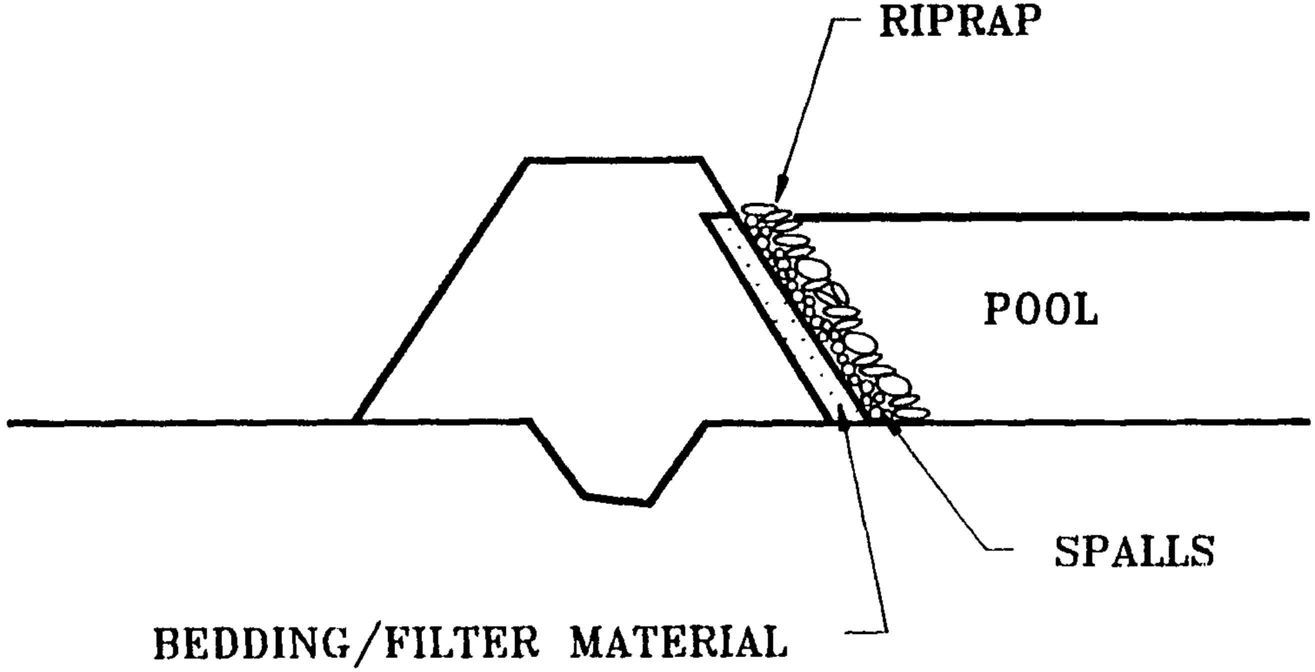
SECTION
Scale $\frac{3}{32}$"=1'-0"

NOTE:
Use this method only for minor wave wash protection, or to fill local holes that are washed in the levee by wave action. The sacks should be placed close together beginning about two feet under the water surface. Each succeeding row of sacks should overlap the preceding row like shingles on a roof. Care should be taken to stagger the joints. All sacks should be tamped or mauled into place so that wave action will not readily wash them away.

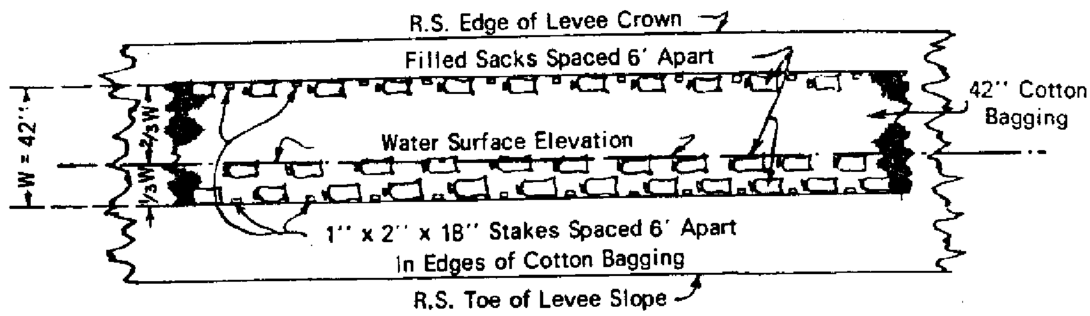
EMERGENCY FLOOD FIGHTING
SACK REVETMENT

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

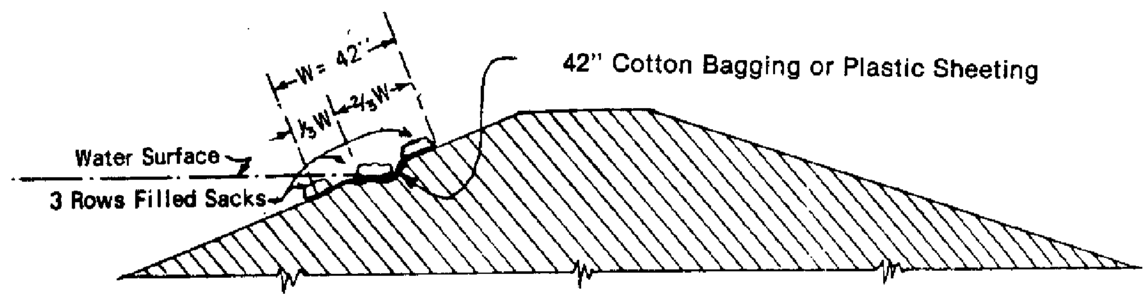
PLATE NO. 21



SLOPE PROTECTION



PLAN



CROSS SECTION

BILL OF MATERIAL
TO CONSTRUCT 180 FT.

1 Roll Jute Cotton Bagging 42" x 180'
90 Filled Sacks
60 Stakes 1" x 2" x 18" = 15 Bd. Ft.

INSTRUCTIONS

Lay 42" cotton bagging (Jute) longitudinally along riverside slope of levee with approximate 2/3 width above water surface.

Weight bagging along edges and at water surface with filled sacks spaced approximately 6' apart. Drive stakes alternately between sacks along both edges of bagging.

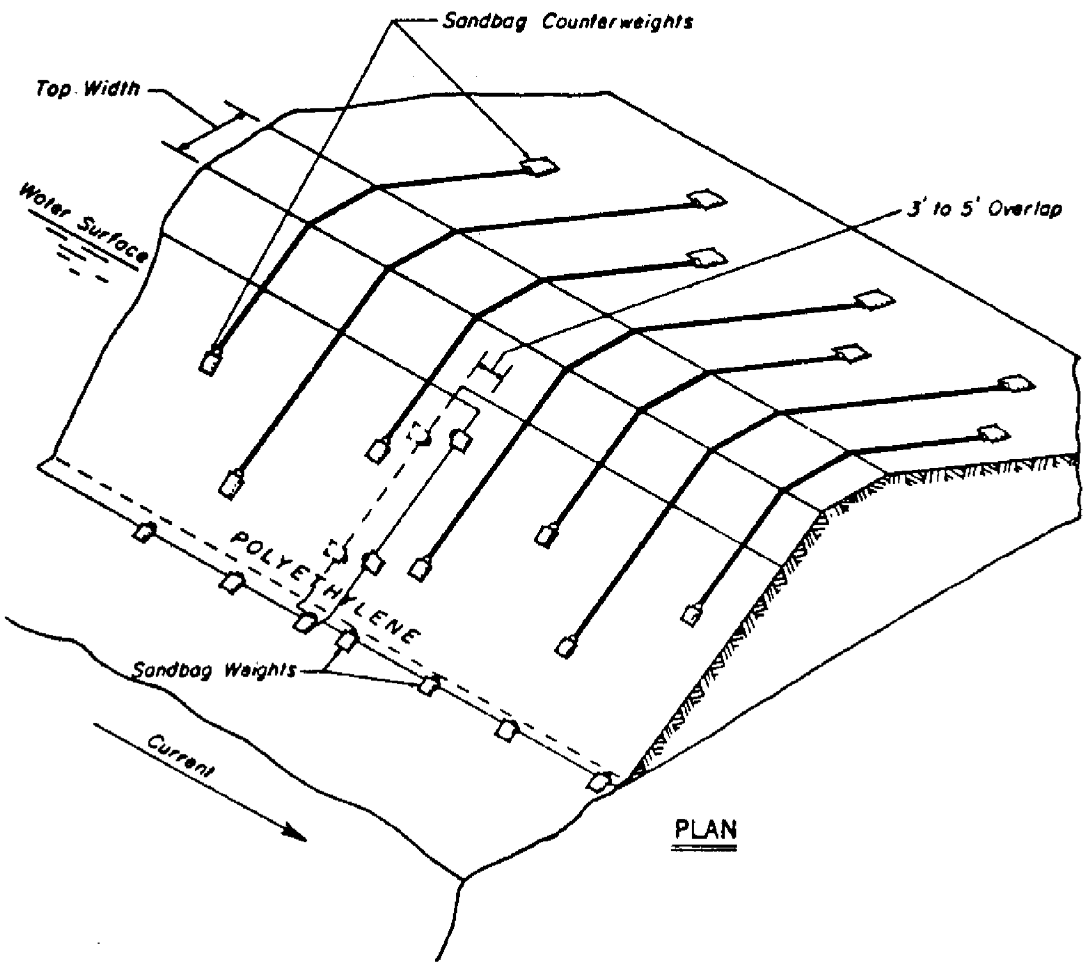
If additional width is required, lace two or more widths of bagging together and lay as desired.

EMERGENCY FLOOD FIGHTING

TYPE OF WAVEWASH PROTECTION

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 23

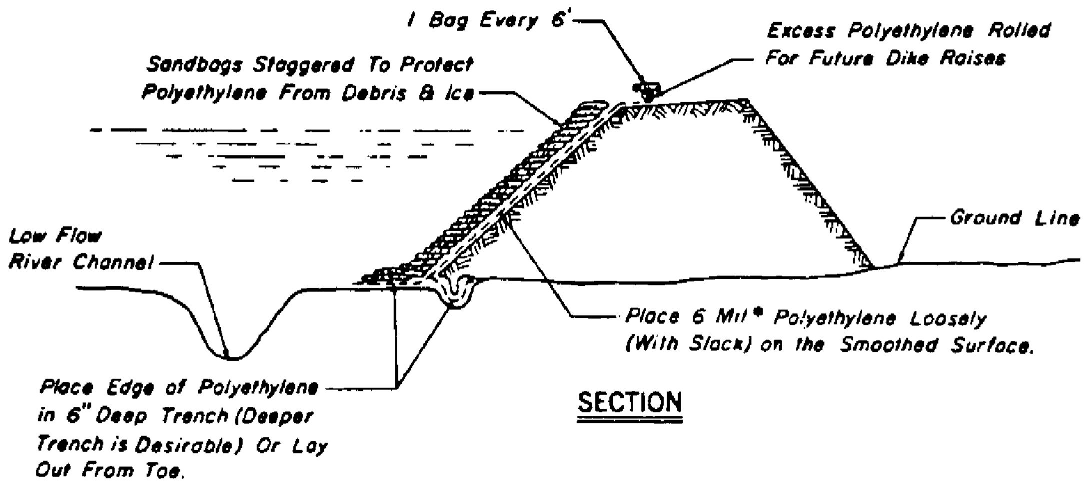


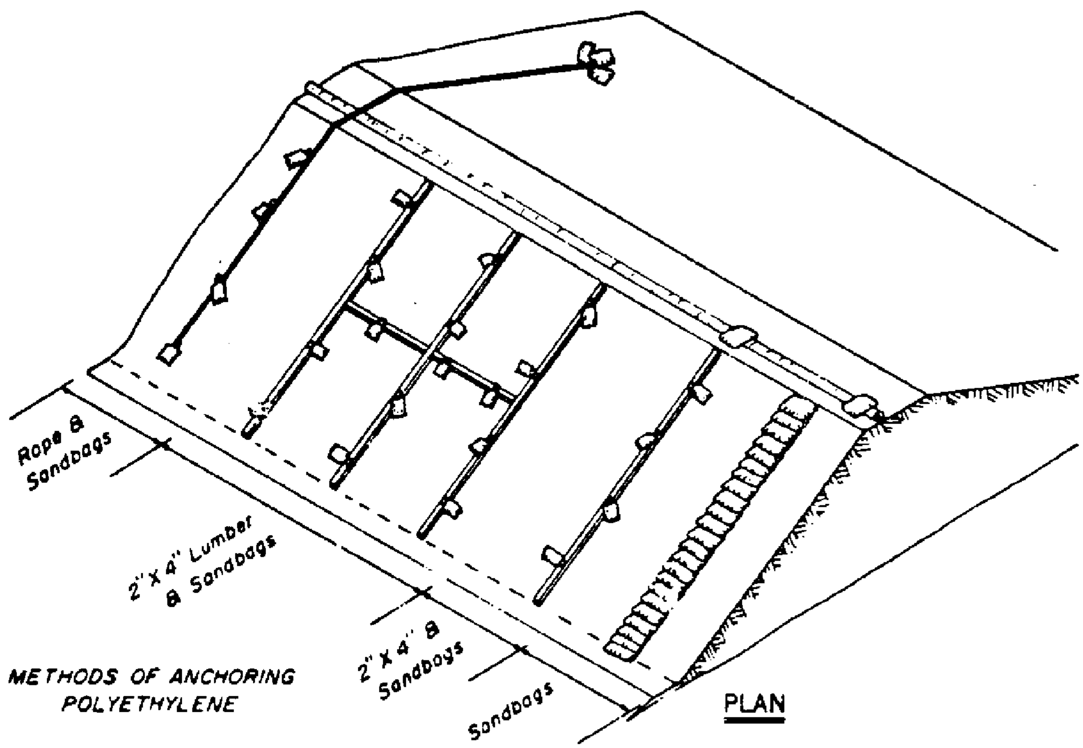
EMERGENCY FLOOD FIGHTING

PLACEMENT OF POLYETHYLENE SHEETING IN THE WET

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 24

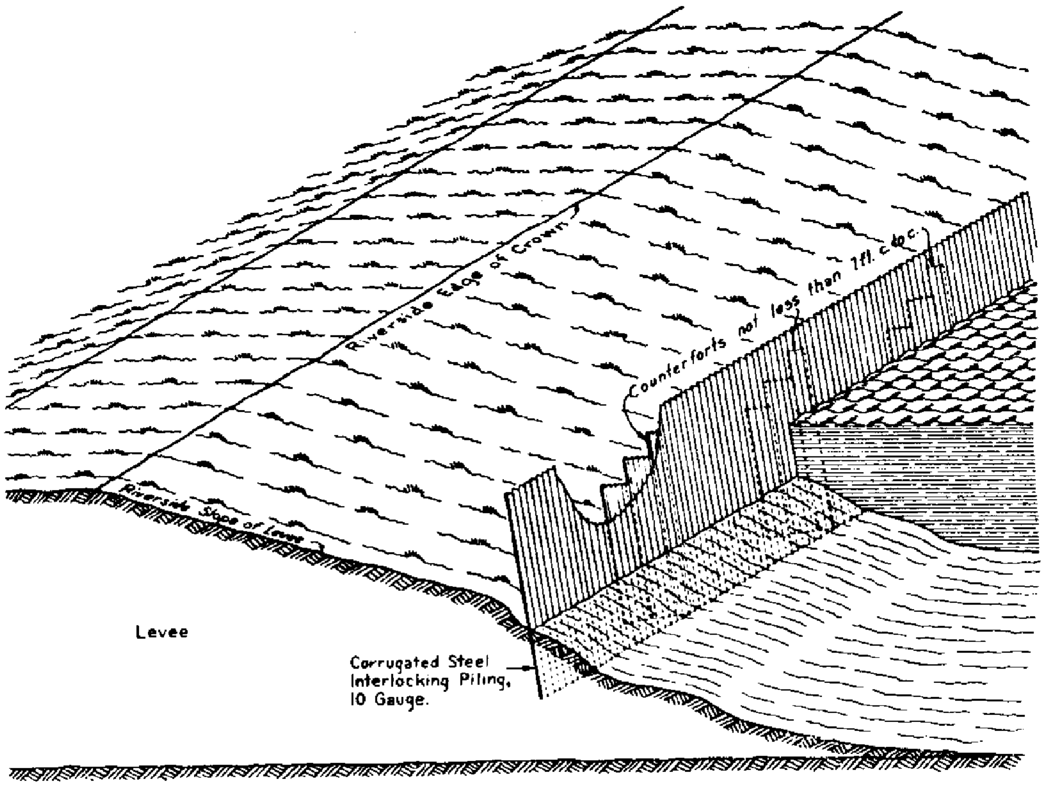


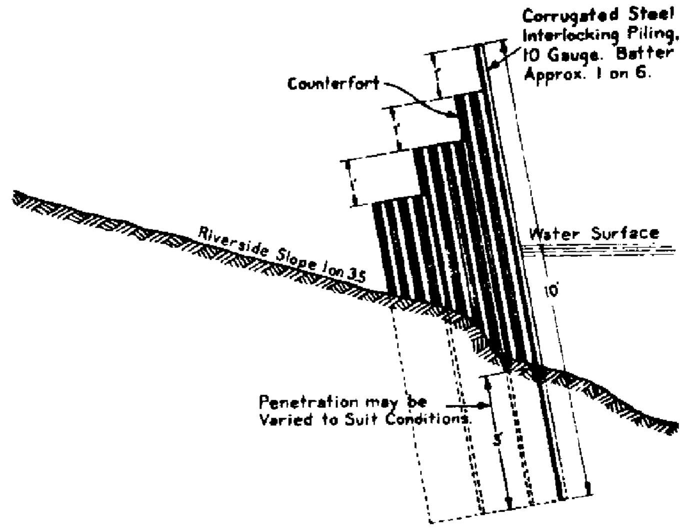


* 6 Mil Black Polyethylene is the most Desirable, 6 Mil Clear Second, 4 Mil Black Third, 4 Mil Clear Fourth & 2 Mil Polyethylene Should Only Be Used As A Last Resort.

EMERGENCY FLOOD FIGHTING POLYETHYLENE LEVEE PROTECTION

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA





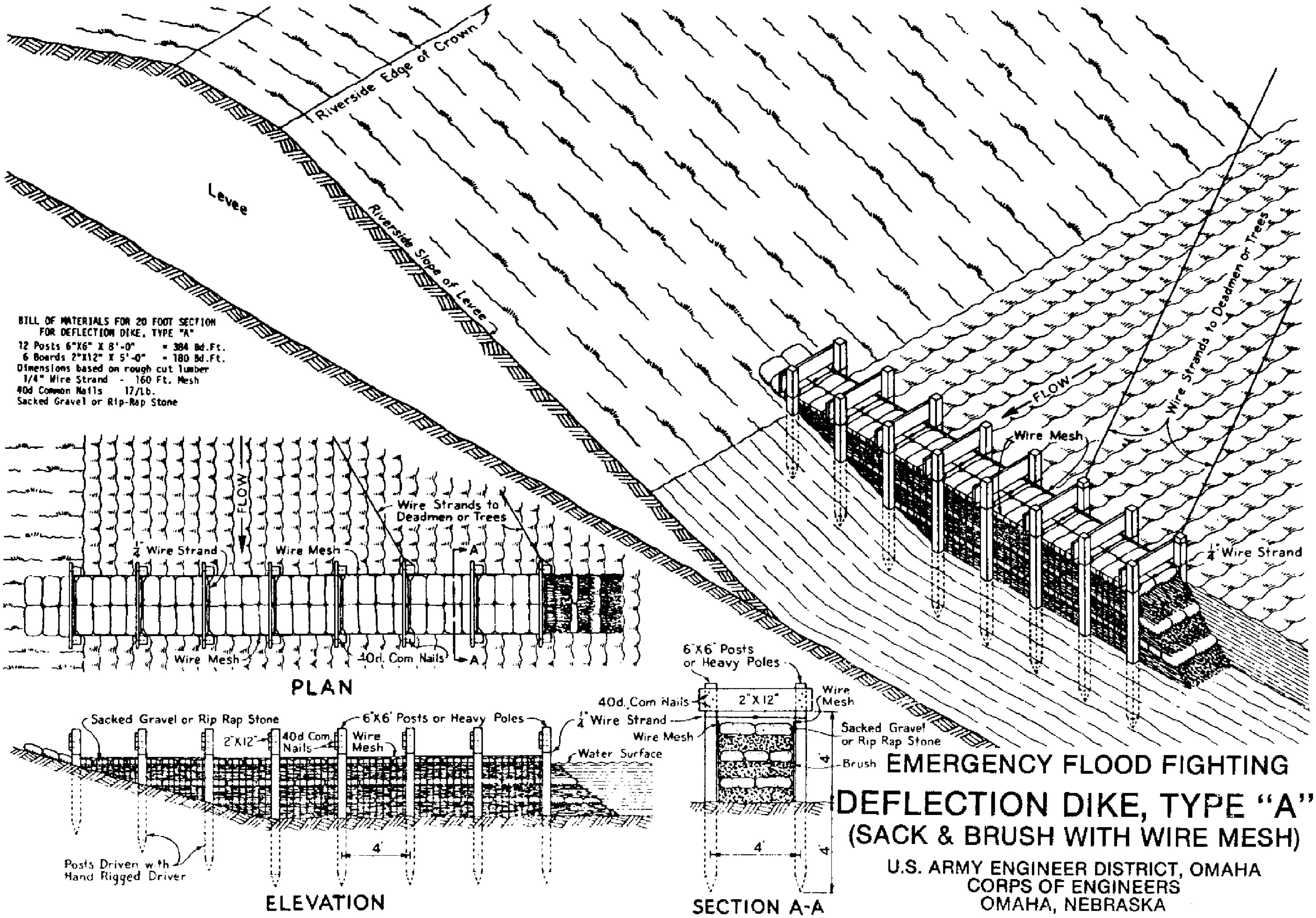
SECTION

EMERGENCY FLOOD FIGHTING

STEEL PILING REVETMENT

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 26



BILL OF MATERIALS FOR 20 FOOT SECTION FOR DEFLECTION DIKE, TYPE "A"

12 Posts 6"X6" X 8'-0" = 384 Bd.Ft.
6 Boards 2"X12" X 5'-0" = 180 Bd.Ft.
Dimensions based on rough cut lumber
1/4" Wire Strand - 160 Ft. Mesh
40d Common Nails 17/Lb.
Sacked Gravel or Rip-Rap Stone

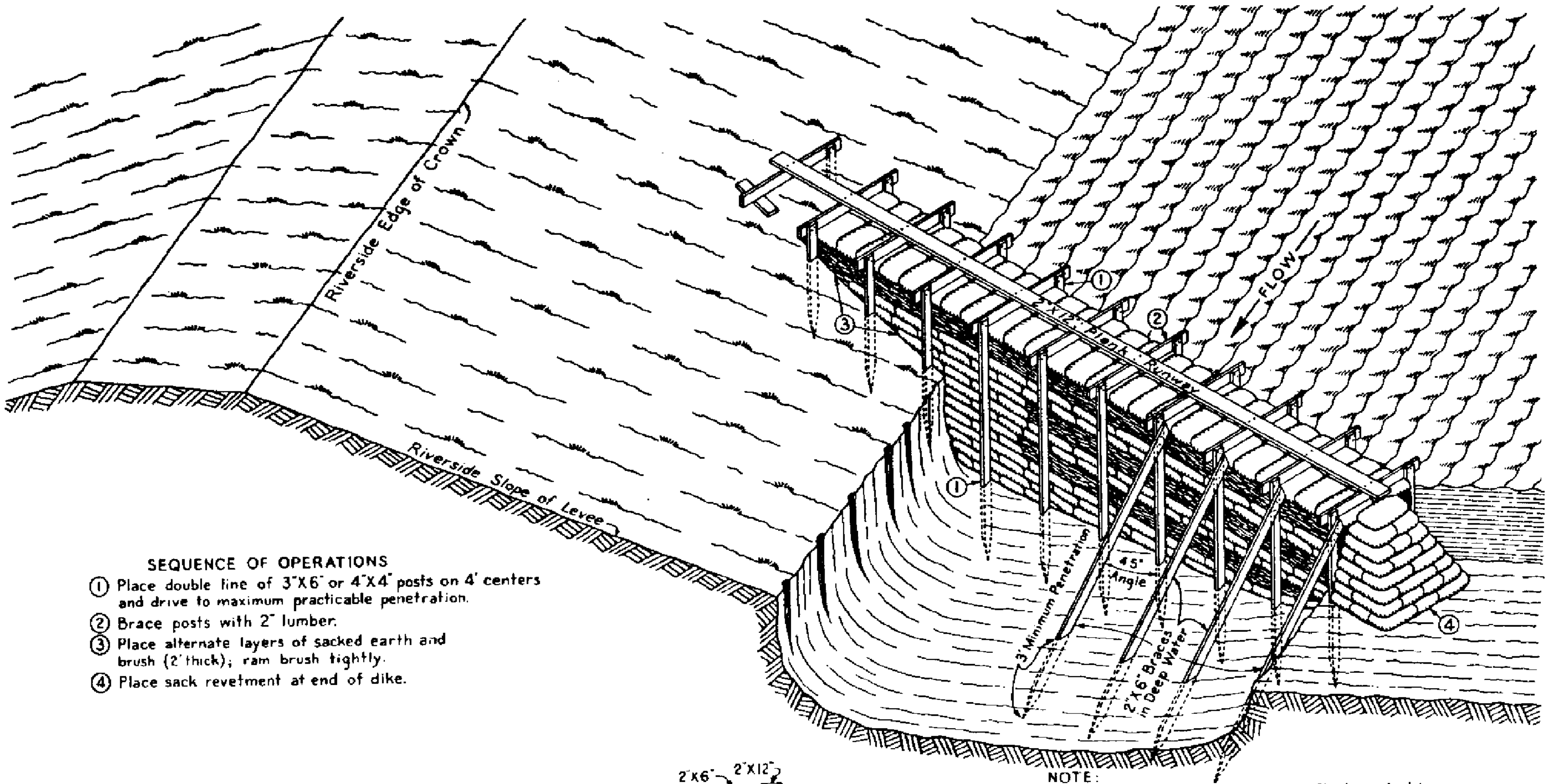
EMERGENCY FLOOD FIGHTING

DEFLECTION DIKE, TYPE "A"

(SACK & BRUSH WITH WIRE MESH)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

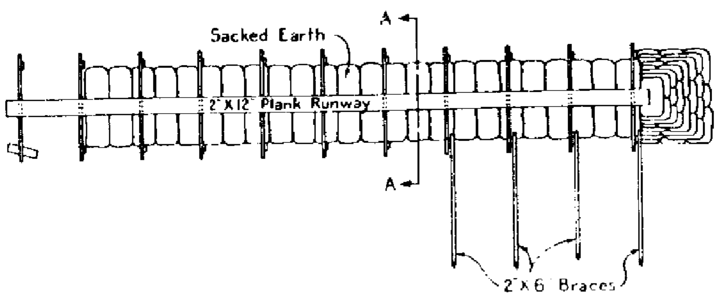
PLATE NO. 27



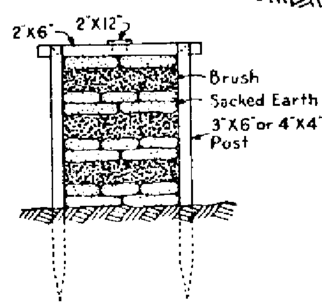
SEQUENCE OF OPERATIONS

① Place double line of 3"X6" or 4"X4" posts on 4' centers and drive to maximum practicable penetration.
② Brace posts with 2" lumber.
③ Place alternate layers of sacked earth and brush (2' thick); ram brush tightly.
④ Place sack revetment at end of dike.

NOTE:
Commence at inshore edge unless floating plant is available and carry progressively to outer end. Placing of brush and sacked earth filler should be undertaken along the full length of dike simultaneously in horizontal layers to an elevation of 1' above anticipated high water.



PLAN

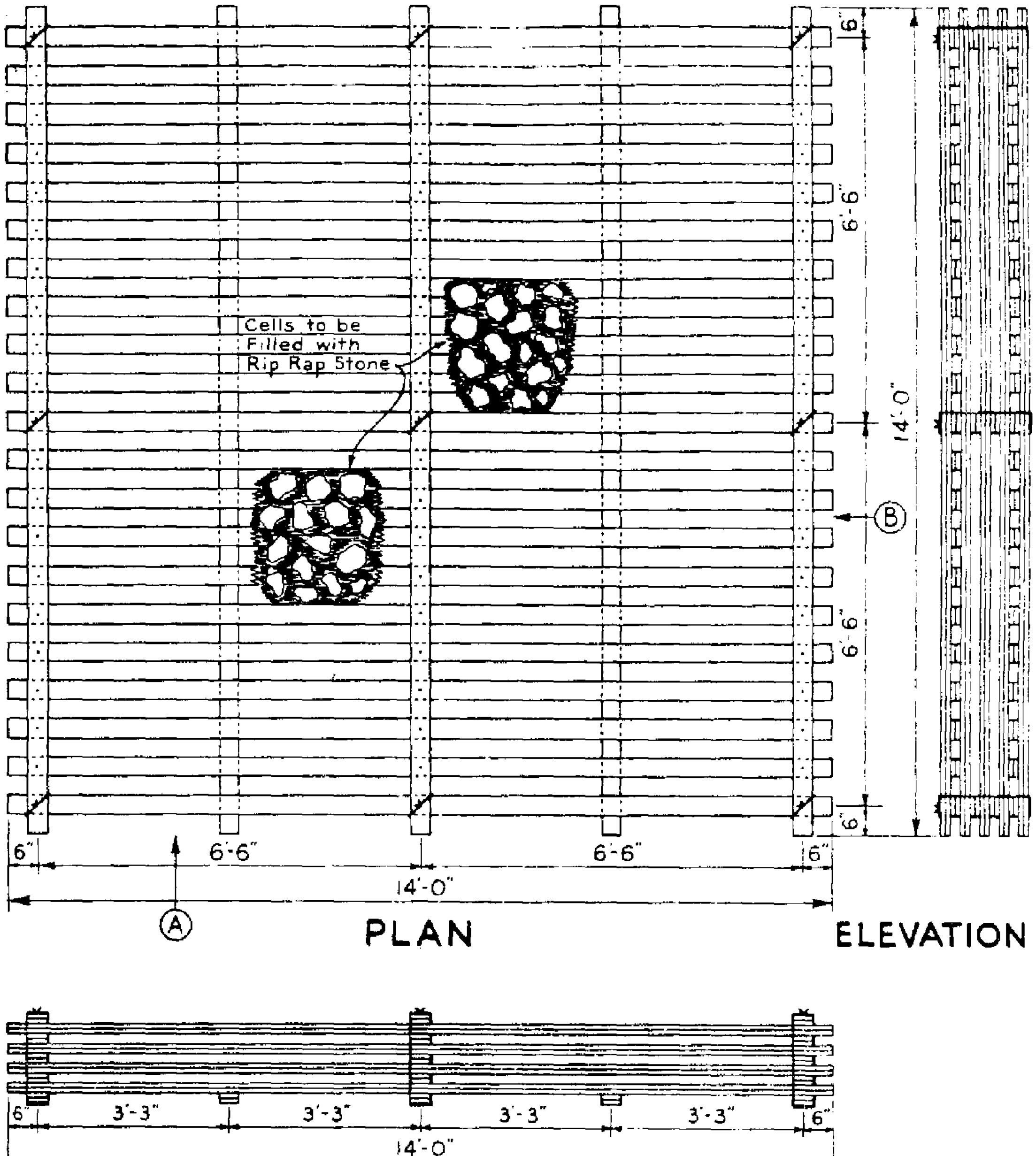


SECTION A-A

EMERGENCY FLOOD FIGHTING
DEFLECTION DIKE, TYPE "B"
(SACK & BRUSH)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 28



ELEVATION "A"

NOTE:
Cribs constructed of double thicknesses of 1"X4"X14' lumber. Nail all intersections with 1-20d. nail. Each intersection of walls securely fastened by a loop of $\frac{1}{4}$" strand, tightly twisted. If rock or concrete blocks are unobtainable, sacks filled with gravel or soil cement may be used.

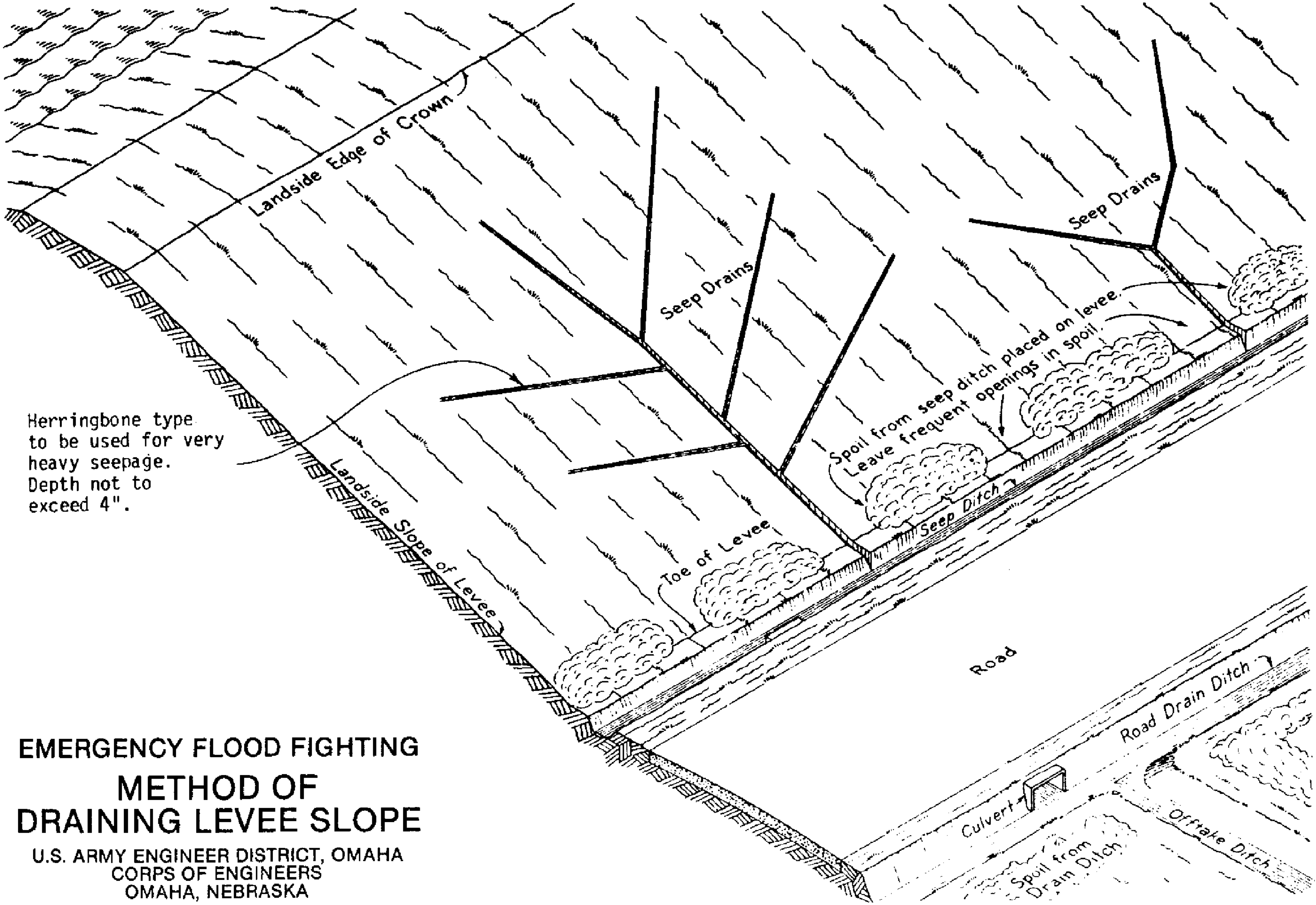
BILL OF MATERIALS
Dimensions based on rough cut lumber

140 Pcs. 1"X4"X14' = 653 Bd. Ft.
12 Lbs. 20d. Common Nails
60 Ft. $\frac{1}{4}$" Strand
$1\frac{1}{2}$ Cu. Yds. Rip Rap Stone
Actual quantities. No allowance for waste.

EMERGENCY FLOOD FIGHTING
STONE CRIB
CAVING BANK PROTECTION

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

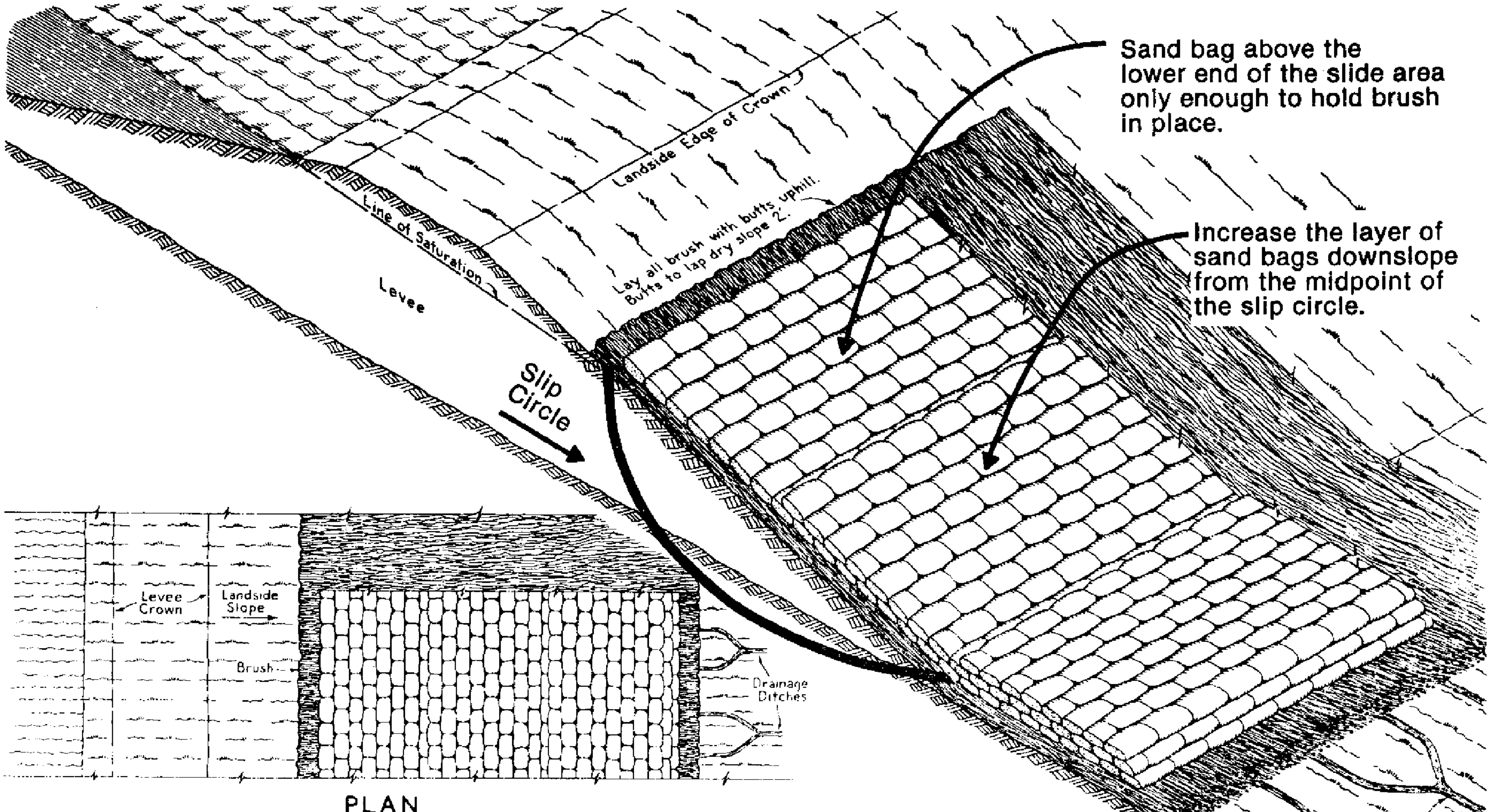
PLATE NO. 29

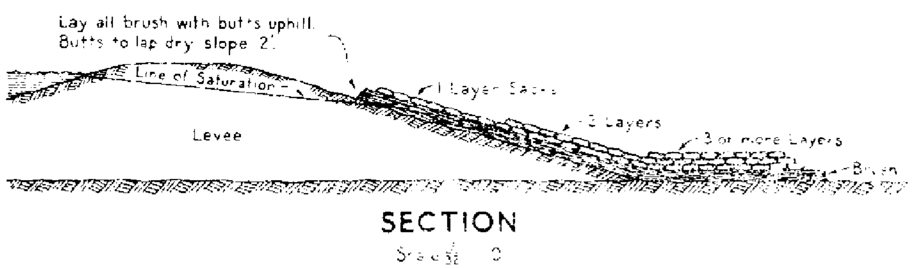


EMERGENCY FLOOD FIGHTING

METHOD OF DRAINING LEVEE SLOPE

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA





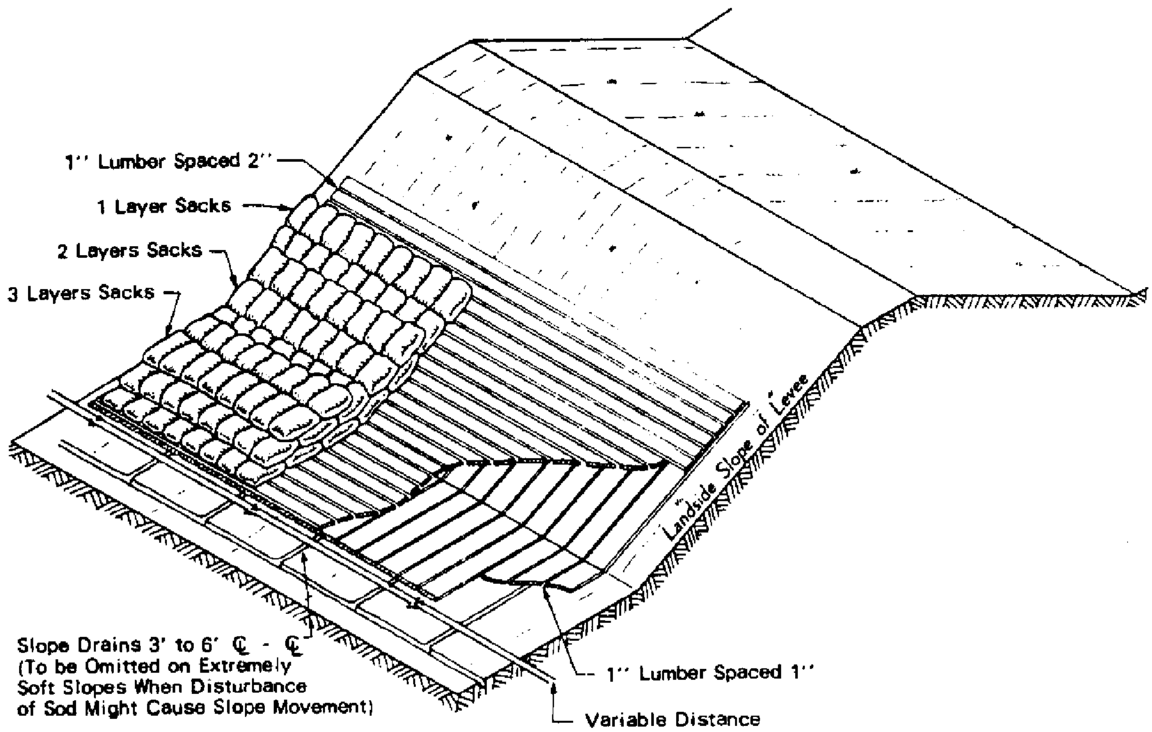
EMERGENCY FLOOD FIGHTING

BRUSH MATTRESS

(FOR TREATMENT OF LEVEE SLOUGHS)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

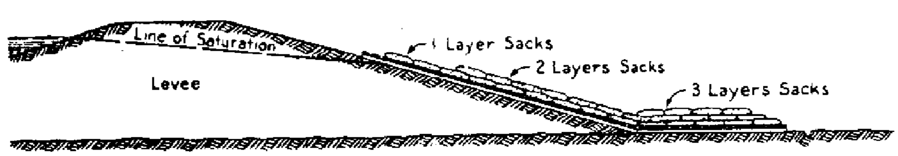
PLATE NO. 31



PLAN

Material Required for 100 Sq. Ft.
180 F.B.M. 1'' x 6'' or 1'' x 8'' Lumber
1 Lb. 8d Common Nails

Dimensions based on rough cut lumber



SECTION

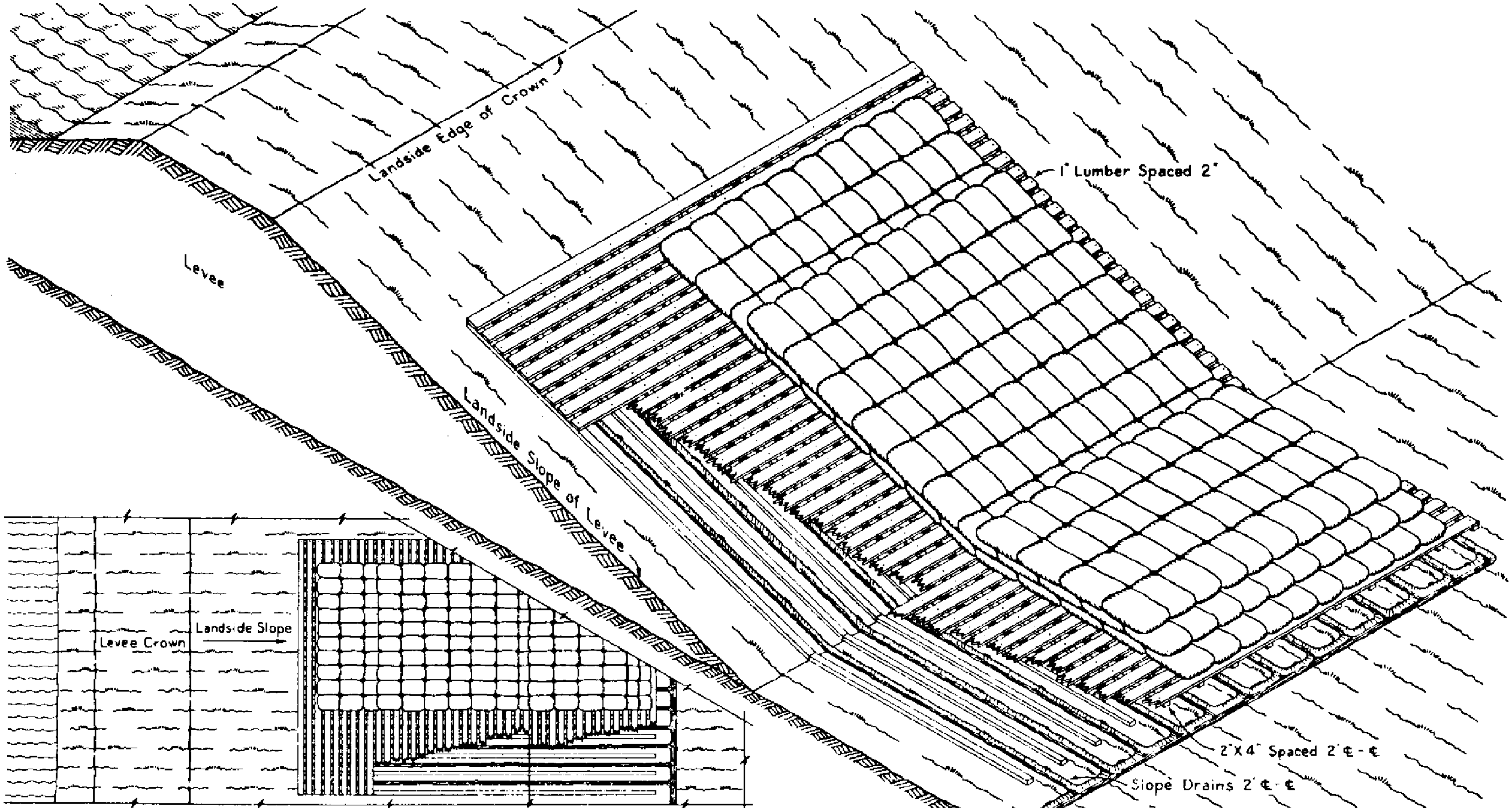
EMERGENCY FLOOD FIGHTING

BOARD MATTRESS-STANDARD TYPE

(FOR TREATMENT OF LEVEE SLOUGHS)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

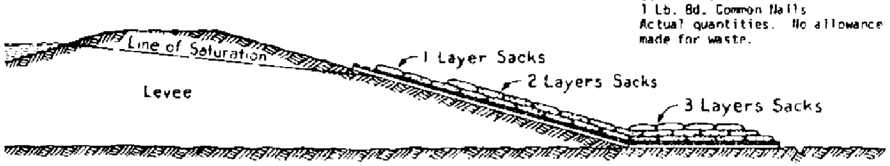
PLATE NO. 32



PLAN

MATERIAL REQUIRED FOR 100 SQ. FT.

Dimensions based on rough cut lumber
90 F B M 1"X6" or 1"X8" Lumber = 60 Bd.Ft.
36 F B M 2"X4" Lumber = 24 Bd.Ft.
1 Lb. 8d. Common Nails
Actual quantities. No allowance made for waste.



SECTION

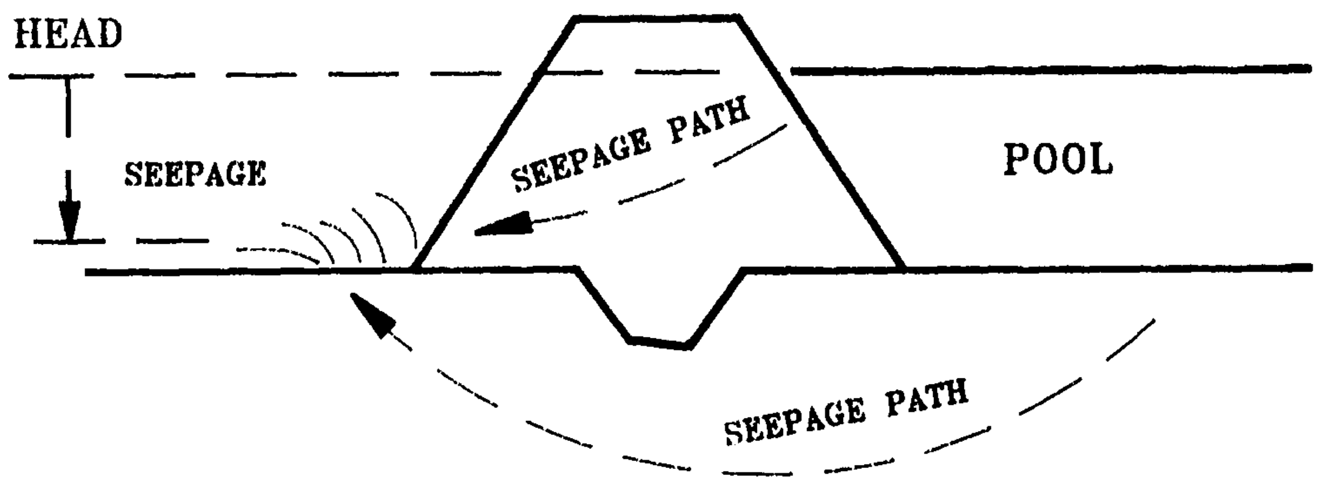
EMERGENCY FLOOD FIGHTING

BOARD MATTRESS-STRINGER TYPE

(FOR TREATMENT OF LEVEE SLOUGHS)

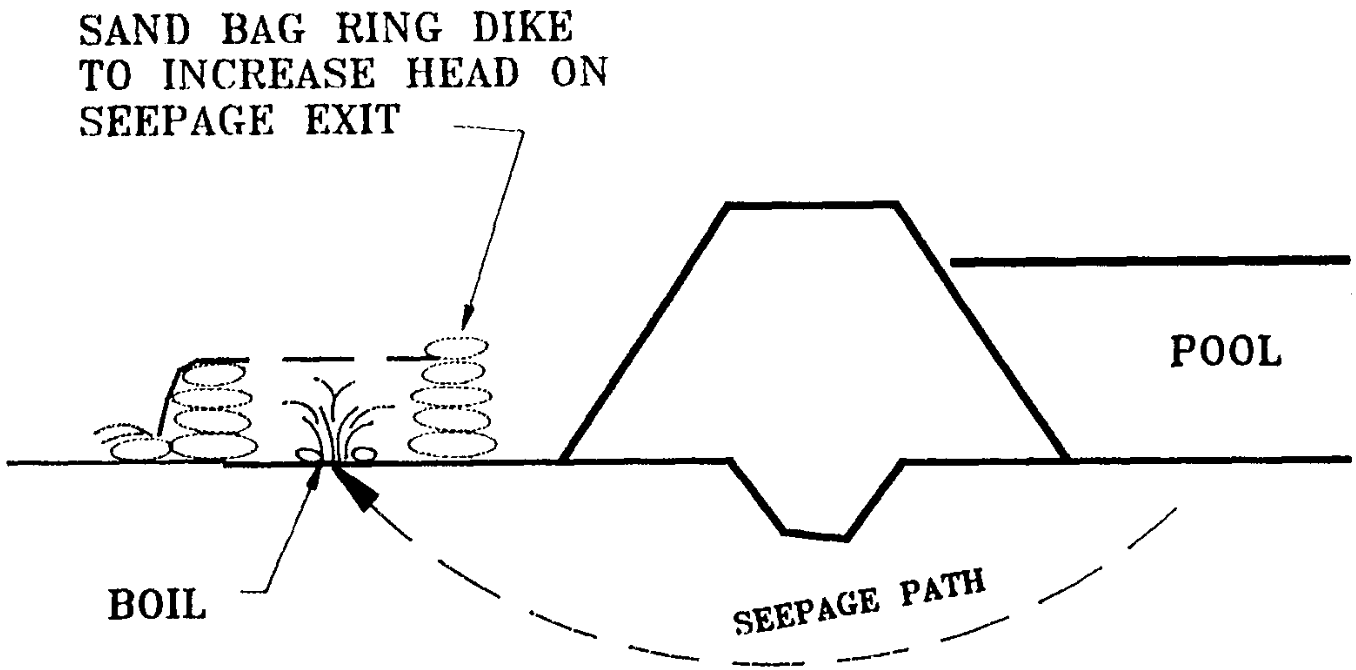
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 33

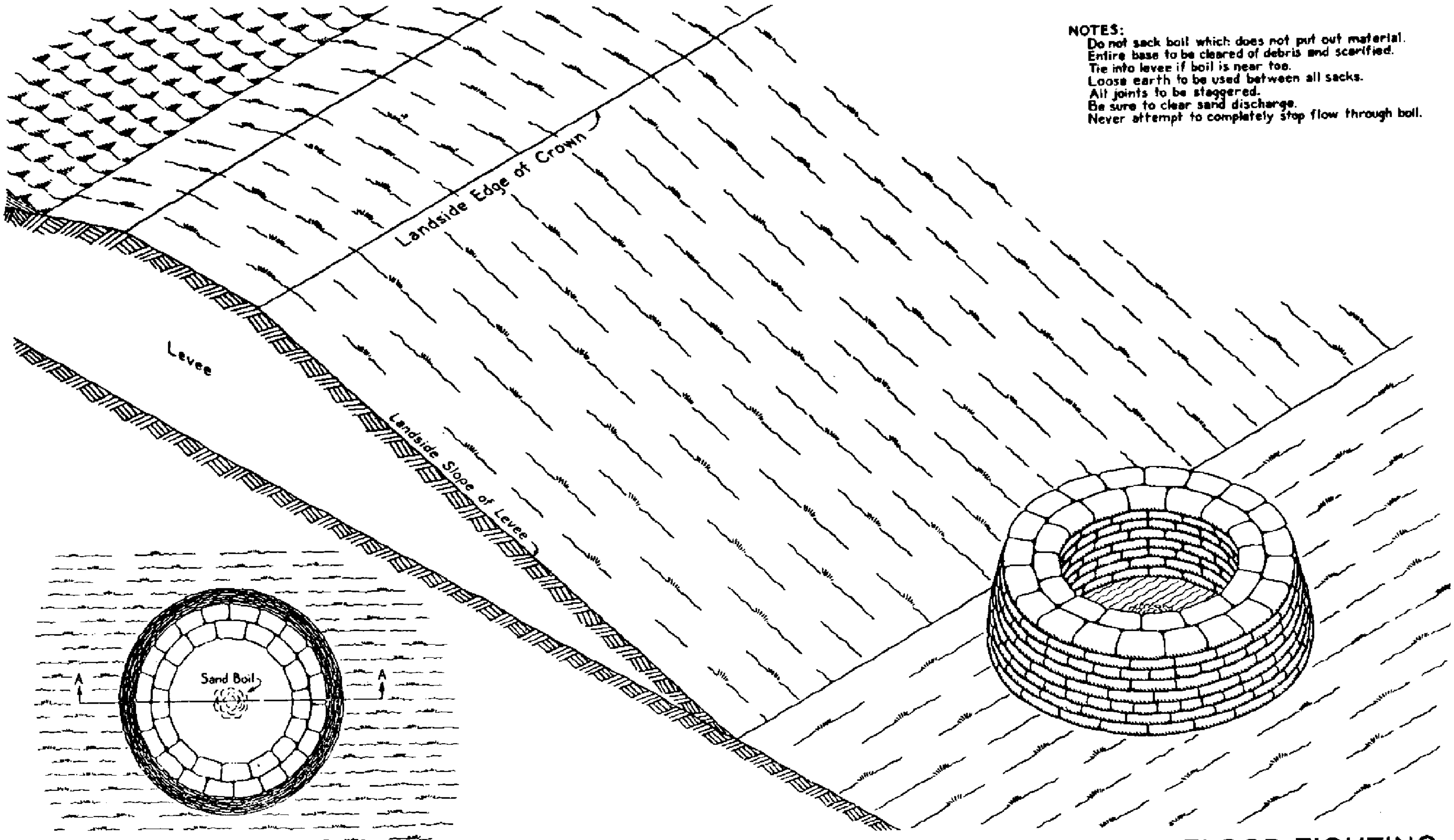


LOWER POOL TO REDUCE HEAD

PLATE NO. 34

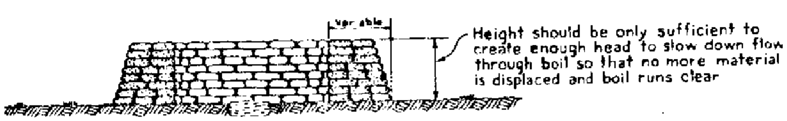


SAND BAG RING DIKE



NOTES:
Do not sack boil which does not put out material.
Entire base to be cleared of debris and scarified.
Tie into levee if boil is near toe.
Loose earth to be used between all sacks.
All joints to be staggered.
Be sure to clear sand discharge.
Never attempt to completely stop flow through boil.

PLAN



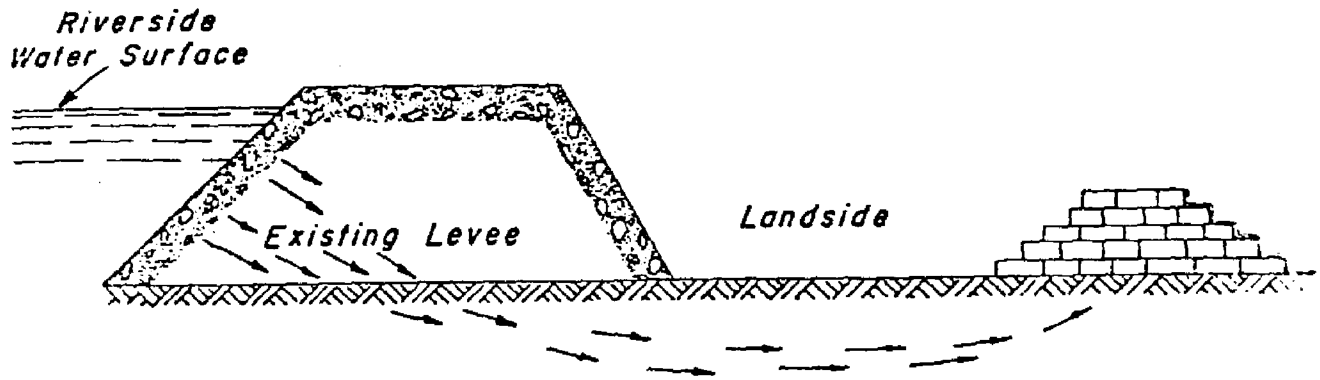
SECTION A-A

EMERGENCY FLOOD FIGHTING

RINGING SAND BOILS WITH SACKED EARTH

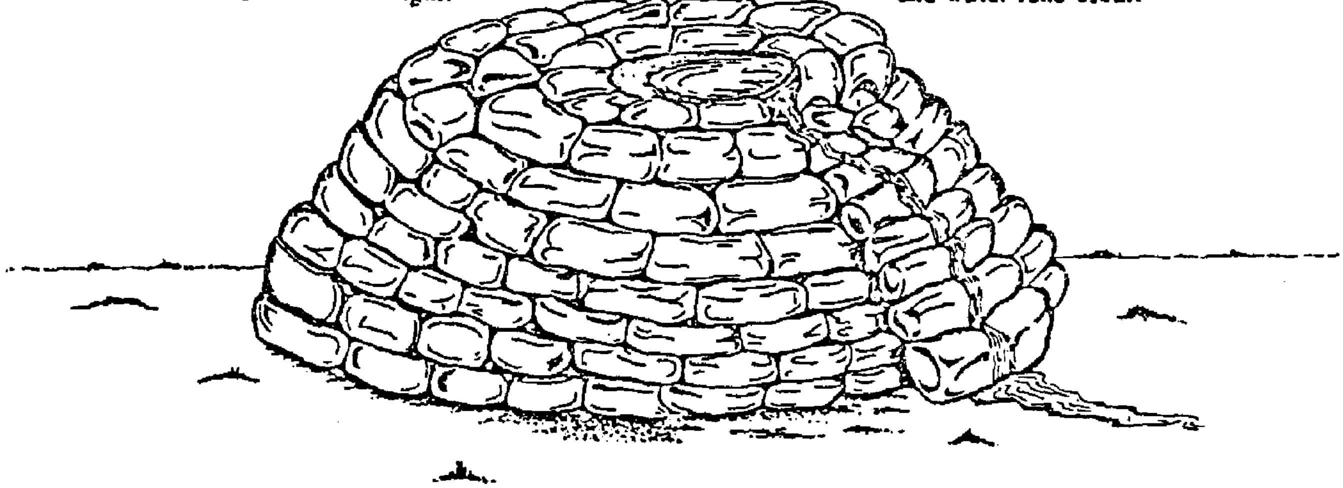
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 36



NEVER completely stop the flow from a sand boil. This may cause the boil to "break out" in an adjacent area.
ALWAYS control the boil to the point it ceases to carry material and water runs clear.

Bottom width should be at least 1½ times the height.



Do not sack boils not carrying material but maintain surveilance during flood periods.

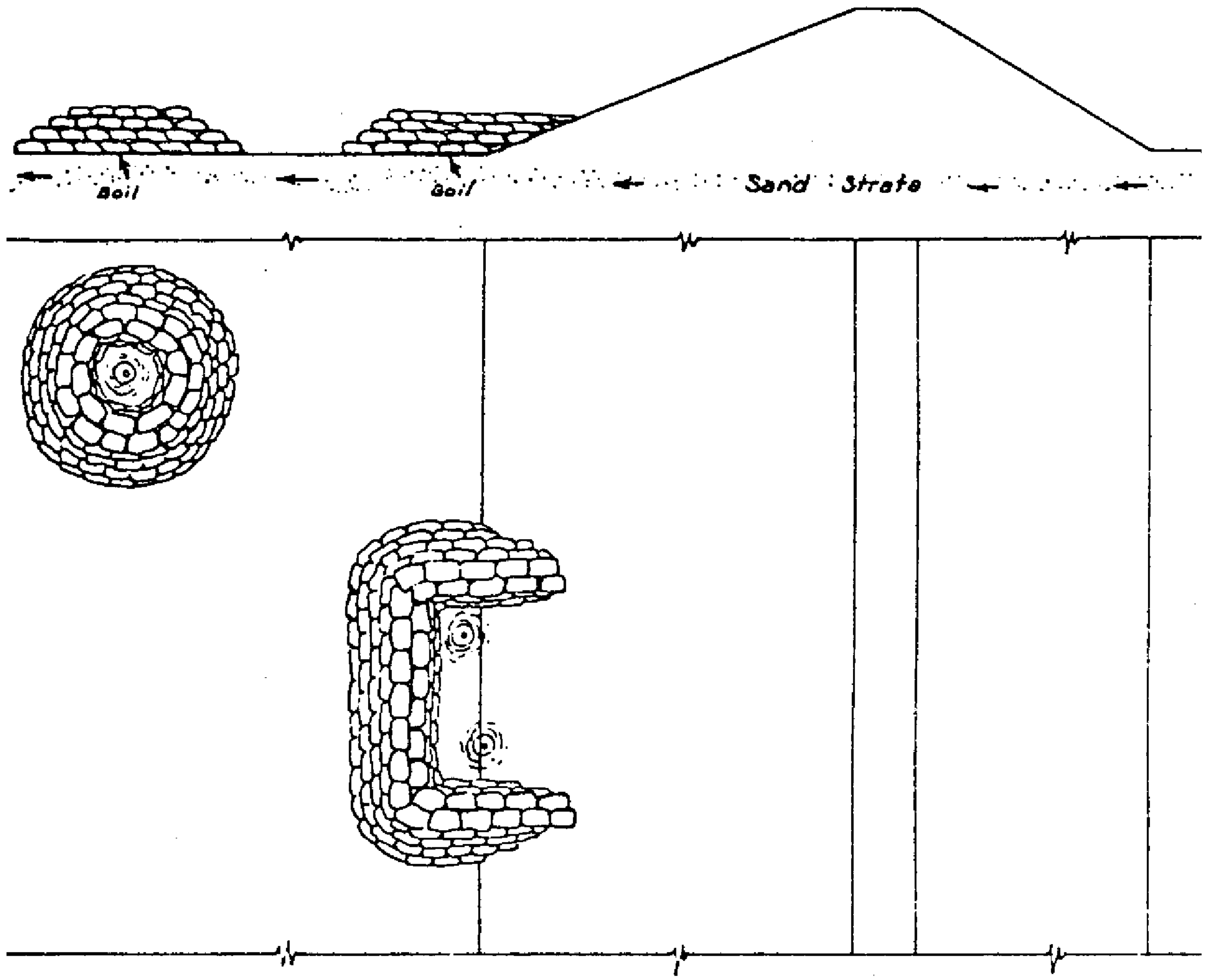
EMERGENCY FLOOD FIGHTING

CONTROL OF SAND BOILS

(AWAY FROM LEVEE)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 37

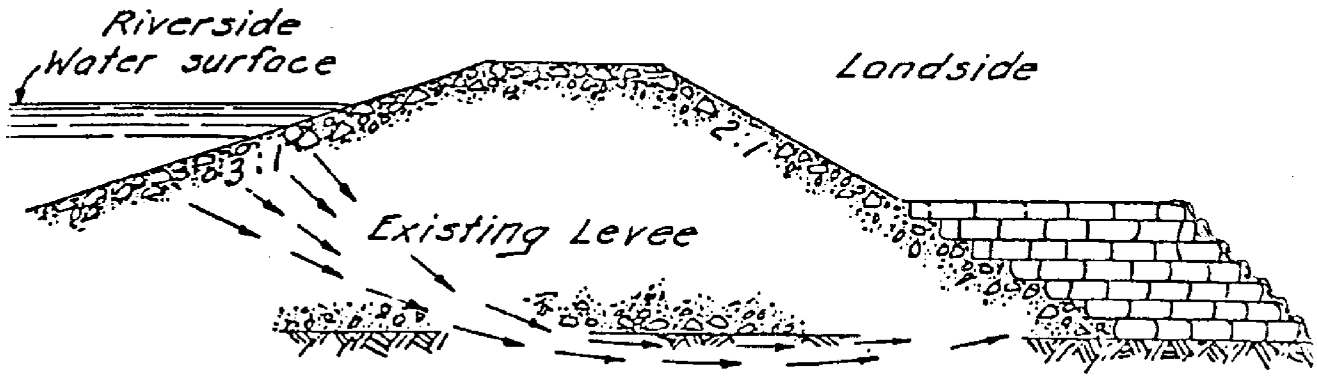


Notes:
Do not stop flow of clear water.
Build ring to height only suficient to stop discharge of material.
Leave a low place in top of ring for a spillway – on side nearest to natural drainage.
Leave sufficient room around boil to allow for caving and to get sacks on solid material to prevent seepage.

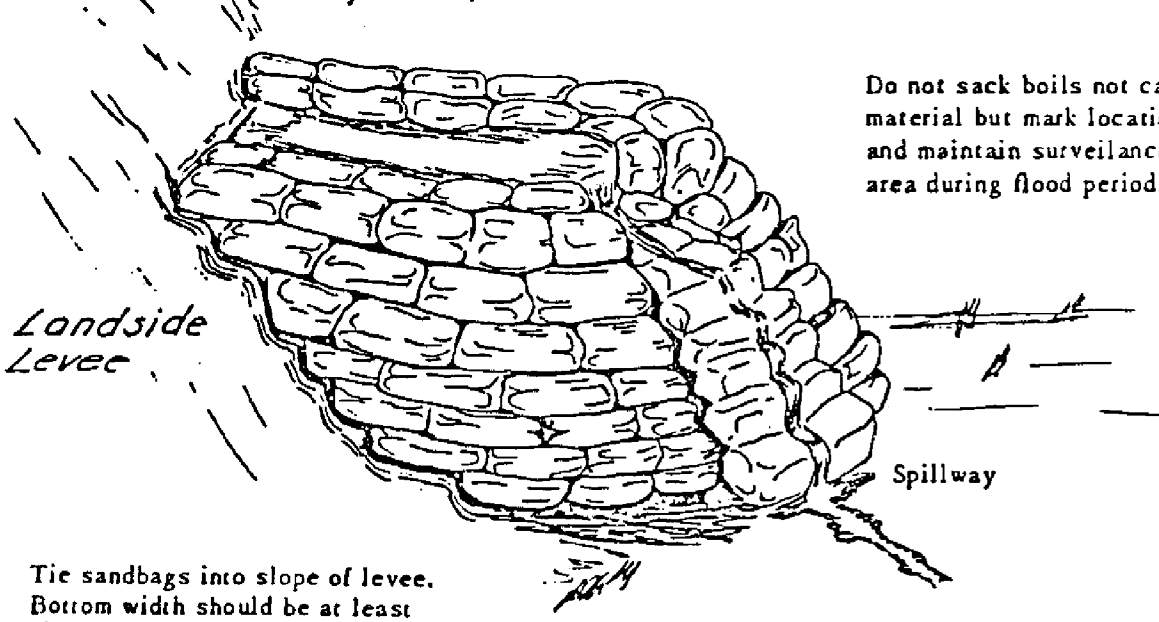
EMERGENCY FLOOD FIGHTING

METHODS OF SACKING SAND BOILS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA



NEVER completely stop the flow from a sand boil. This may cause the boil to "break out" in an adjacent area. ALWAYS control the boil to the point it ceases to carry material, and water runs clear.



Do not sack boils not carrying material but mark location well and maintain surveilance of this area during flood period.

Tie sandbags into slope of levee. Bottom width should be at least 1½ times height.

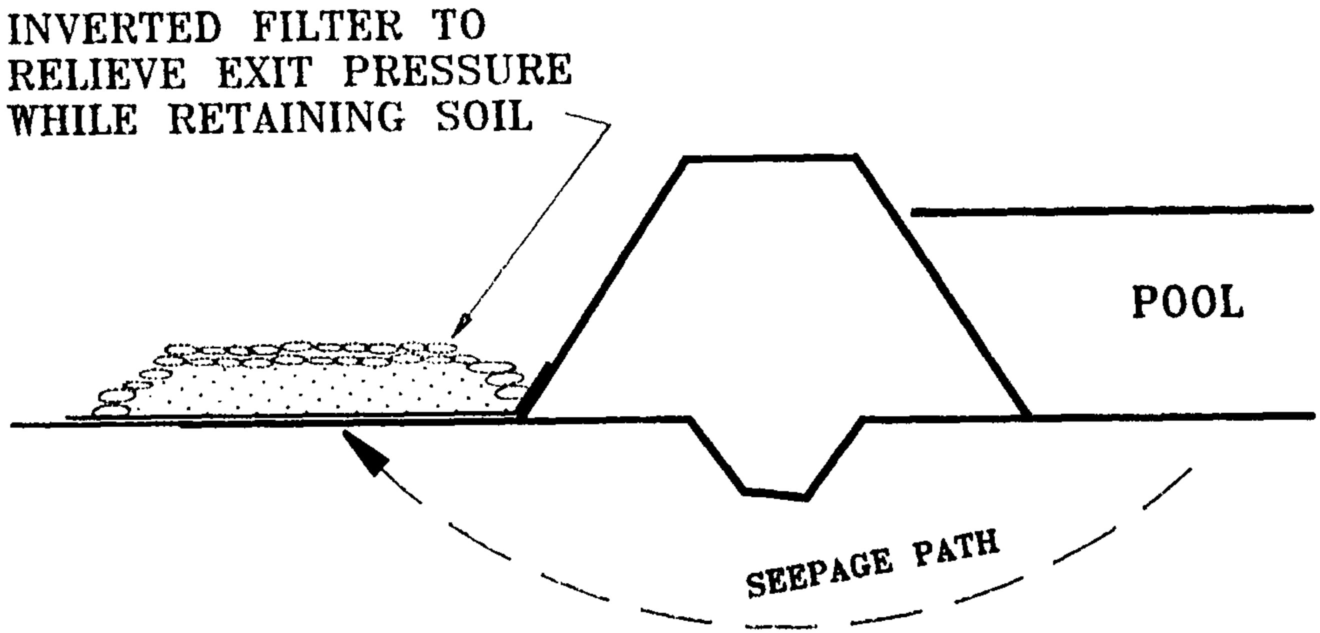
EMERGENCY FLOOD FIGHTING

CONTROL OF SAND BOILS

(NEAR LEVEE)

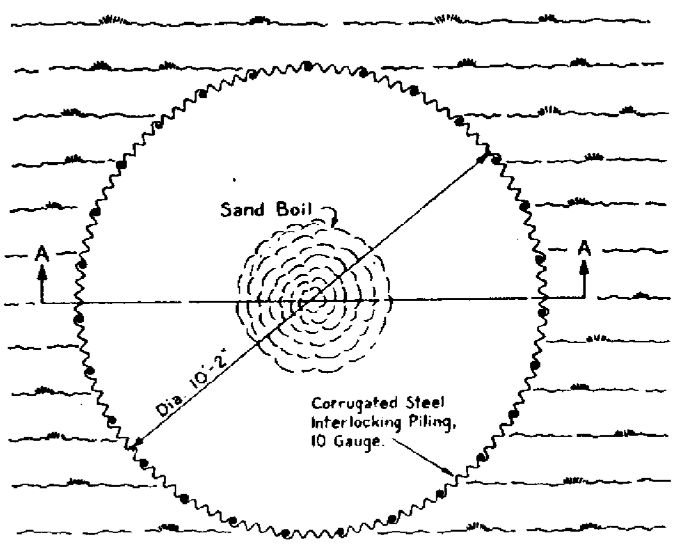
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 39

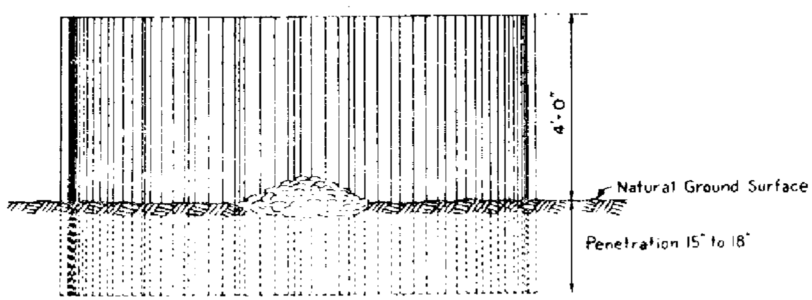


INVERTED FILTER

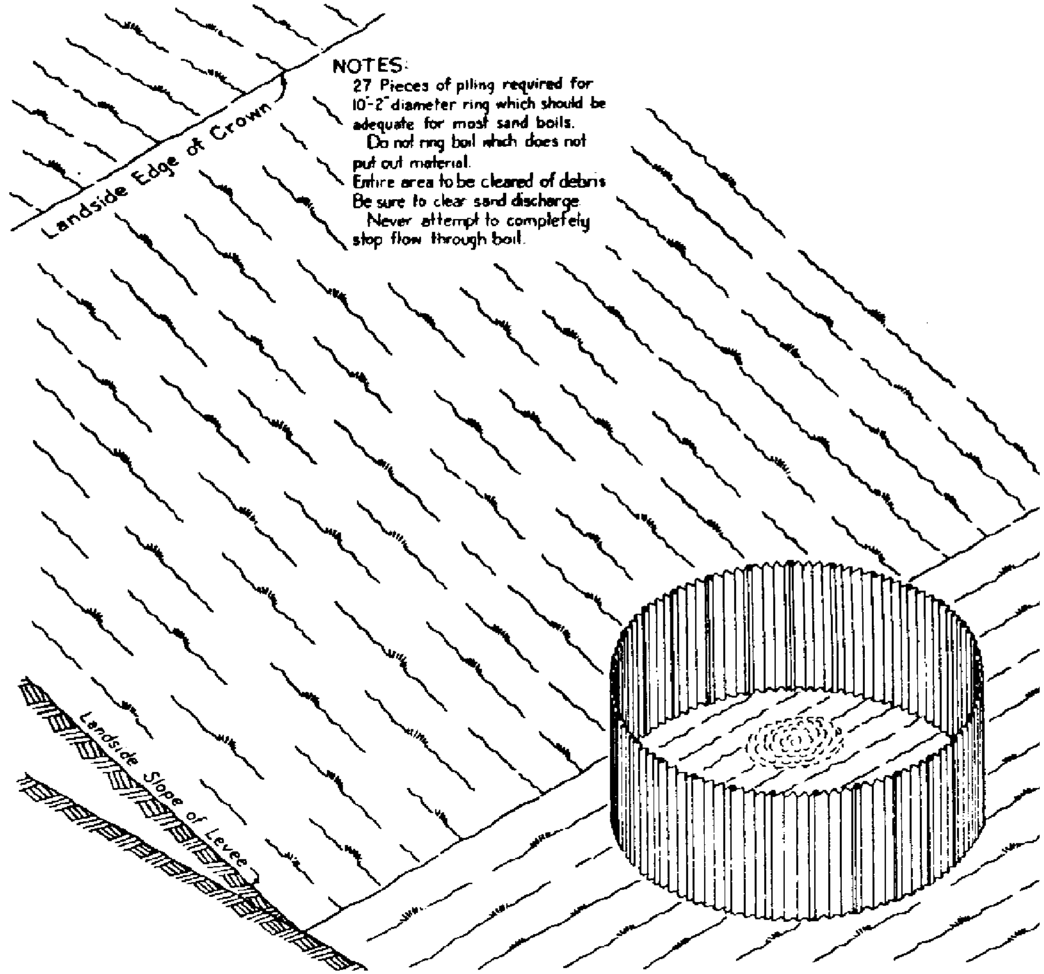
NOTE:
Driving caps will be used. Driving may be effected either by mechanical or hand method.



PLAN



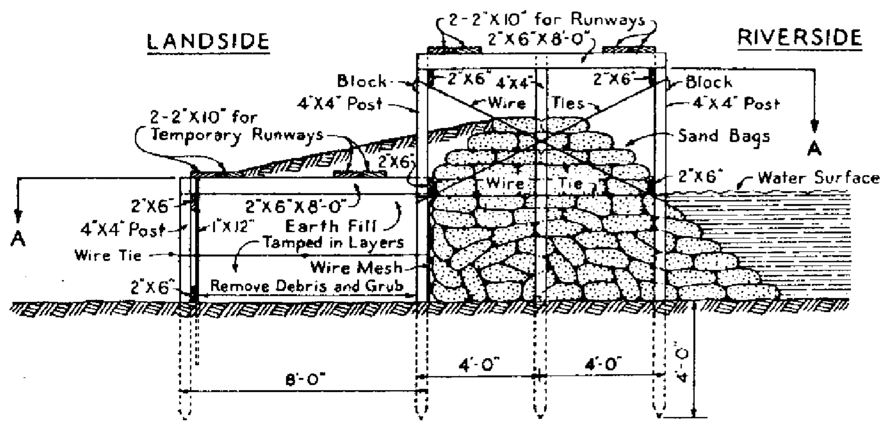
SECTION A-A



EMERGENCY FLOOD FIGHTING

RINGING SAND BOILS WITH STEEL PILING

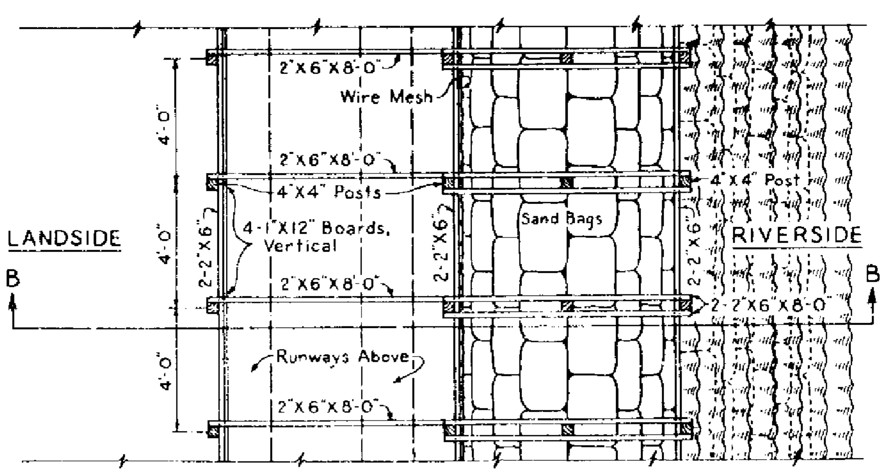
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA



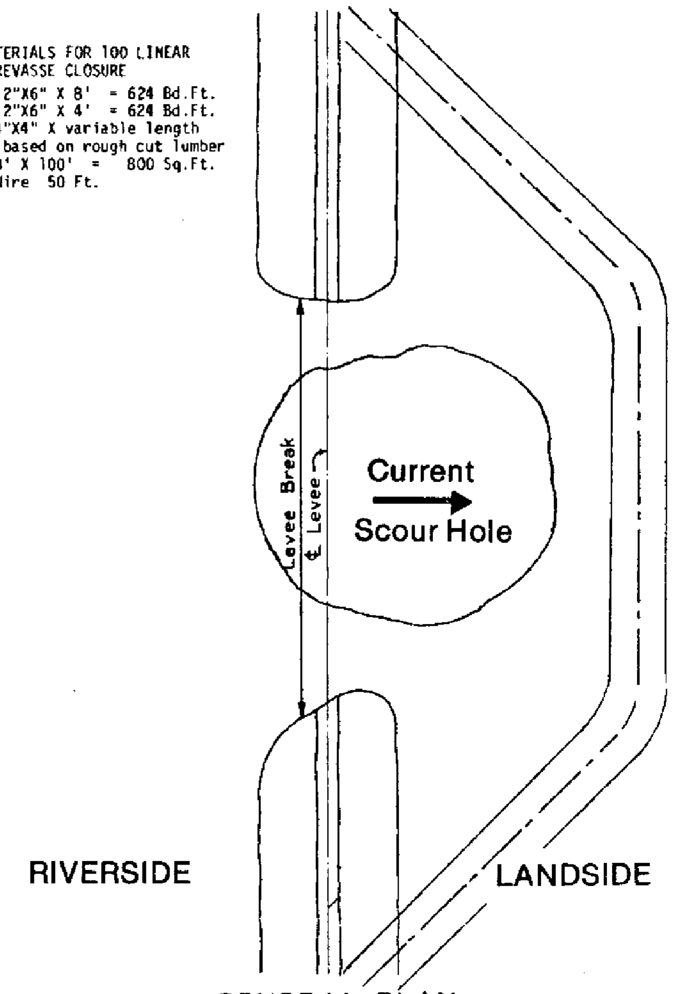
SECTION B-B

BILL OF MATERIALS FOR 100 LINEAR FEET CREVASSE CLOSURE

78 Boards 2"X6" X 8' = 624 Bd.Ft.
156 Boards 2"X6" X 4' = 624 Bd.Ft.
104 Posts 4"X4" X variable length
Dimensions based on rough cut lumber
Wire Mesh 8' X 100' = 800 Sq.Ft.
4 Rolls Wire 50 Ft.



PLAN AT A-A



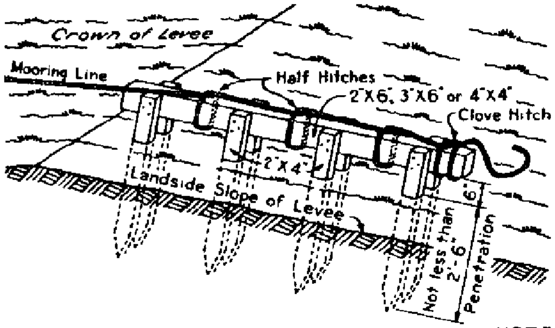
GENERAL PLAN

NOTE:
2 x 4" Braces may be used instead of wire ties.

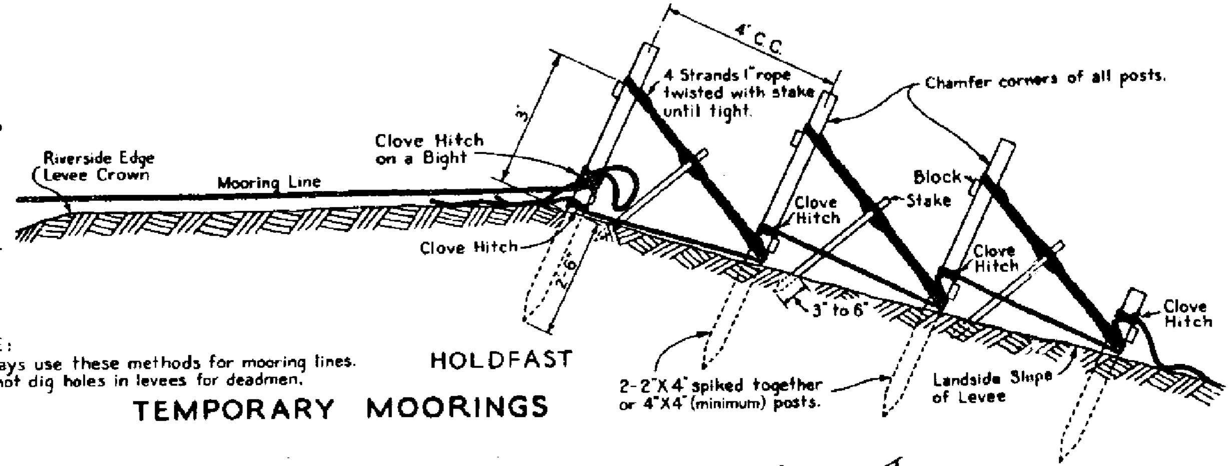
EMERGENCY FLOOD FIGHTING
CREVASSE CLOSURE

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 42



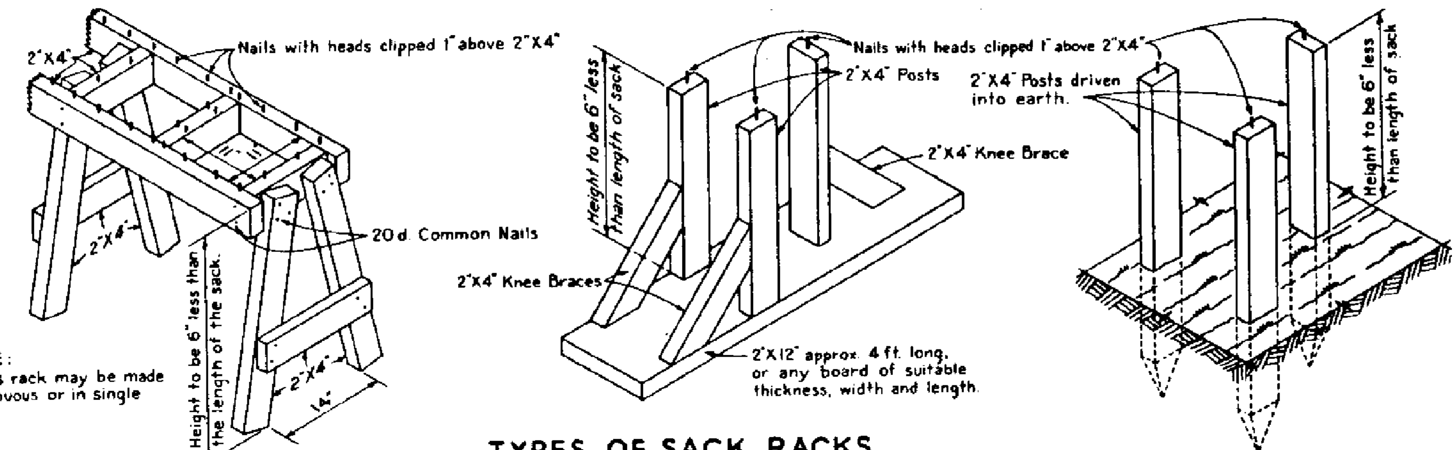
MOORING CLEAT



NOTE:
Always use these methods for mooring lines.
Do not dig holes in levees for deadmen.

HOLDFAST

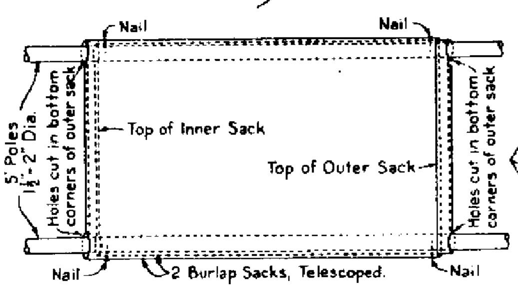
TEMPORARY MOORINGS



NOTE:
This rack may be made continuous or in single units.

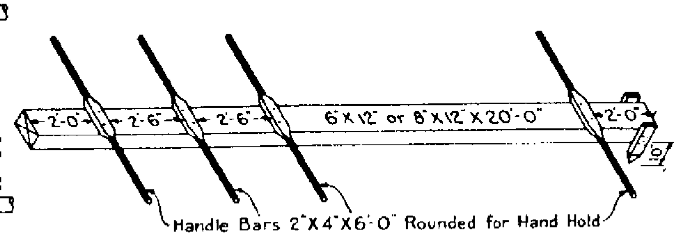
TYPES OF SACK RACKS

WOODEN SACK NEEDLE



HAND BARROW FOR CARRYING FILLED SACKS

Scale 1"=1'-0"



DOLLY OR BABY

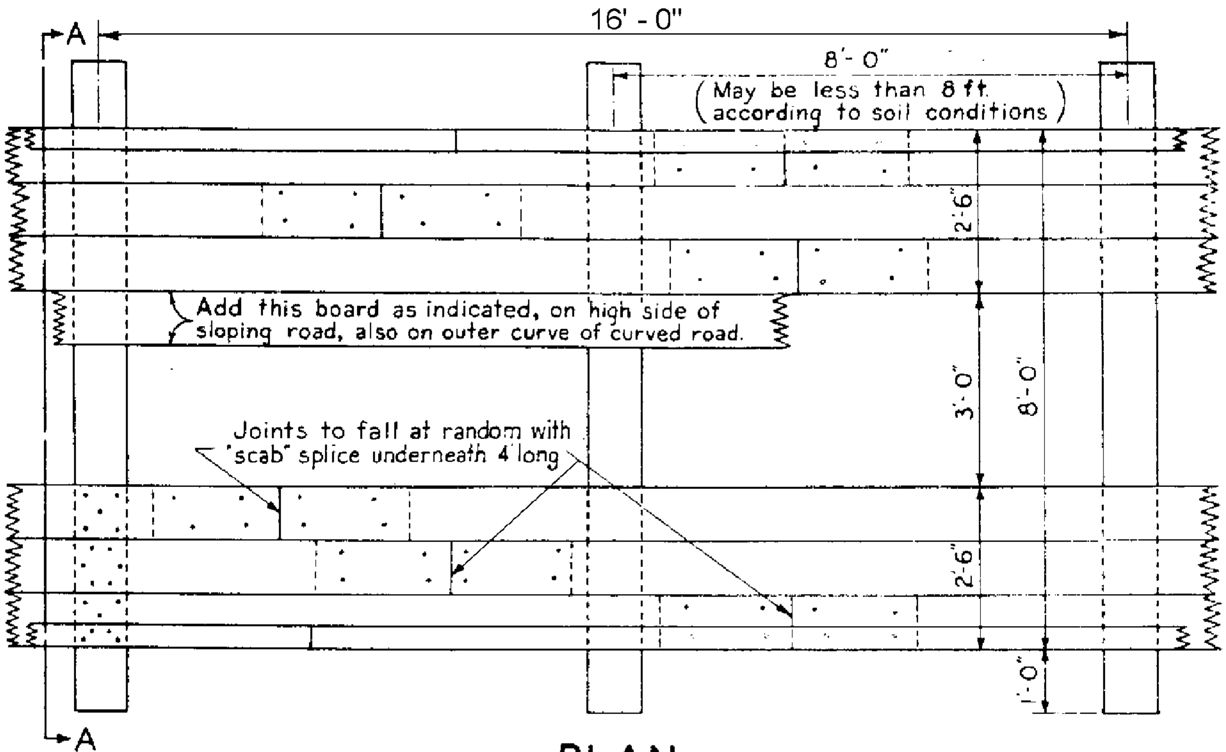
FOR DRIVING POSTS AND SHEATHING BY HAND

EMERGENCY FLOOD FIGHTING

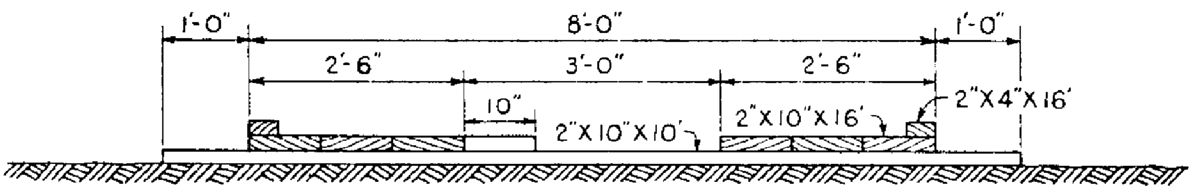
MISCELLANEOUS DETAILS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 43



PLAN
Scale $\frac{3}{8}$" = 1'-0"



SECTION A-A
Scale $\frac{1}{2}$" = 1'-0"

BILL OF MATERIALS FOR 100 LINEAR FEET OF ROADWAY

Cross Members	13 Pcs. 2"X10"X10' =	217 Bd. Ft.
Road Bed	38 Pcs. 2"X10"X16'* =	1014 Bd. Ft.
Guard Rail	13 Pcs. 2"X4"X16'* =	139 Bd. Ft.
	Total	1370 Bd. Ft.

18 Lbs. 30d. Common Nails
10 Lbs. 60d. Common Nails

Kind of Lumber: Hardwood, Rough.

Actual quantities. No allowance made for waste.

NOTE:
Where foundation is very soft, 12 ft. flooring should be used with cross members at 6 ft. centers. In this case add approximately 33$\frac{1}{3}$% or $\frac{1}{3}$ to Bill of Materials at left, for 100 ft. of roadway.

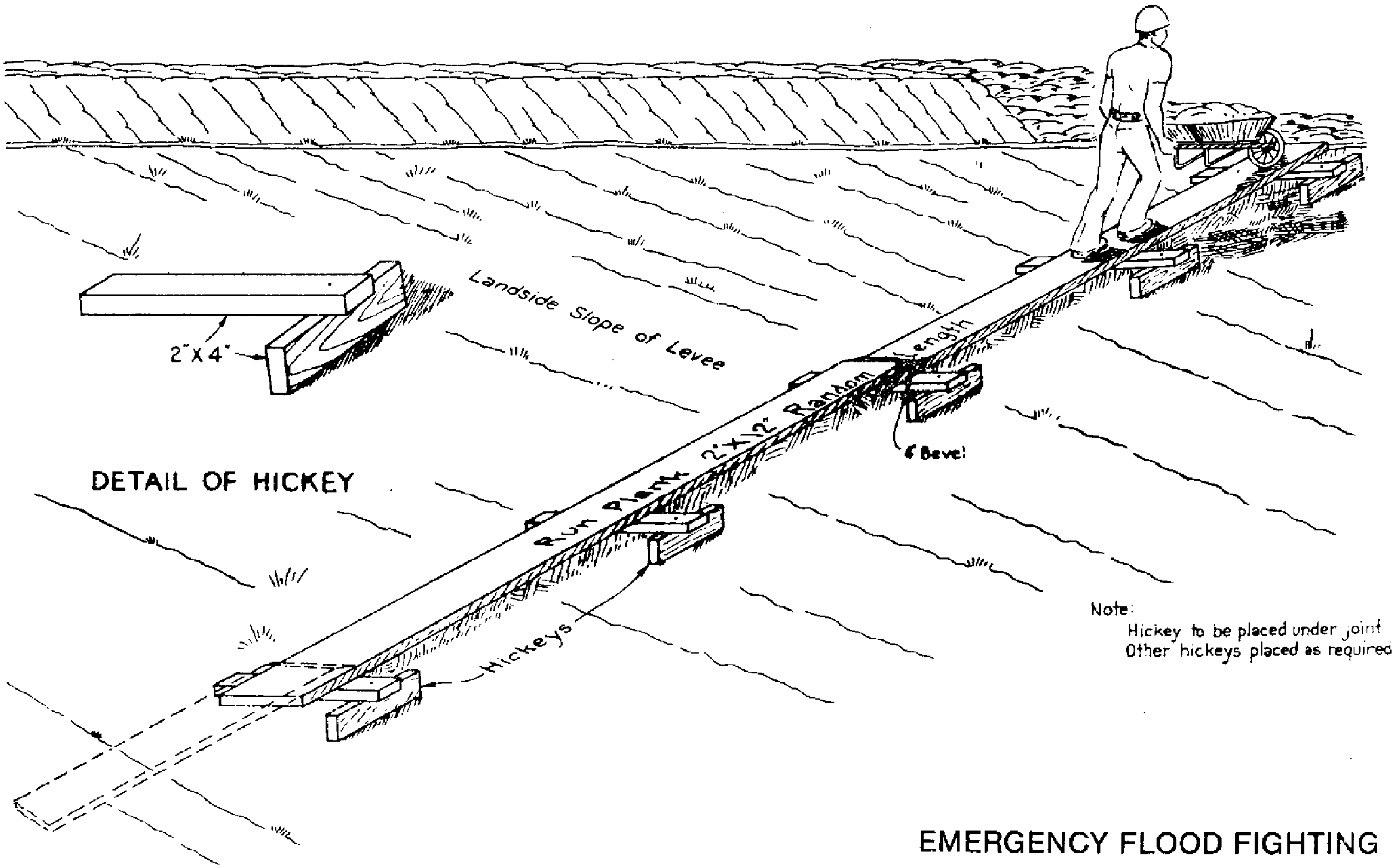
* Random not less than 12'

EMERGENCY FLOOD FIGHTING

PLANK ROAD

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 44

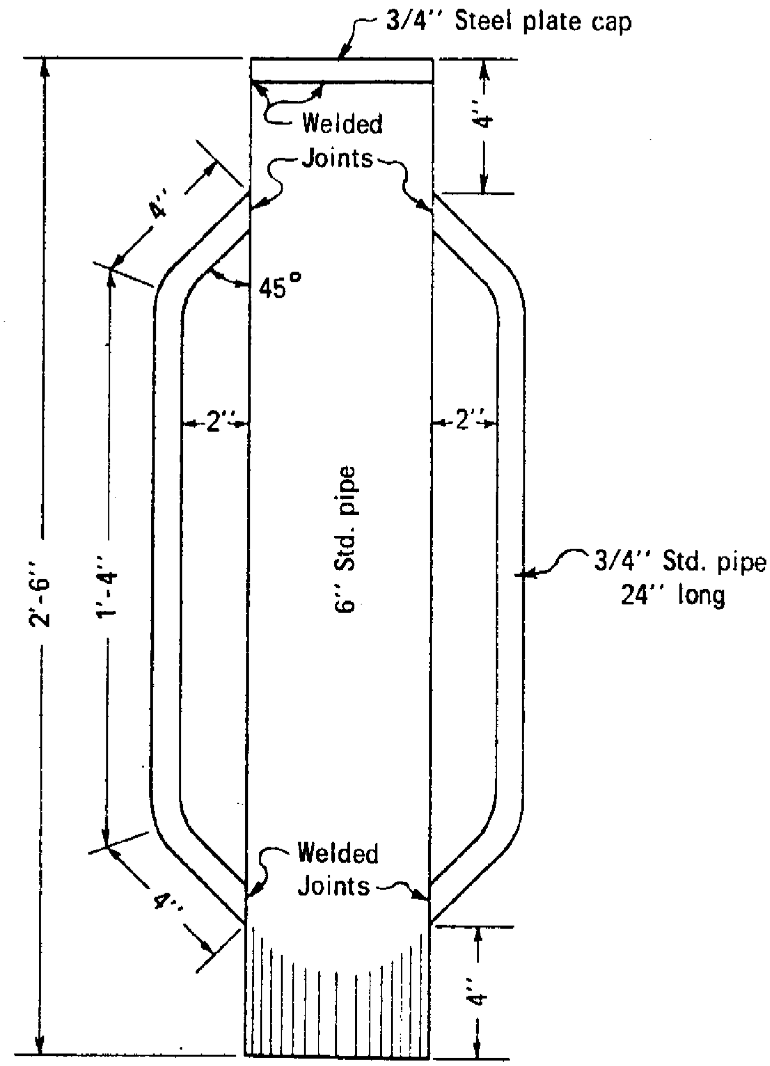


EMERGENCY FLOOD FIGHTING

PLANK RUNWAY

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 45



Scale 3/16" = 1"

EMERGENCY FLOOD FIGHTING

POST DRIVER

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE NO. 46

APPENDIX C

EXHIBIT NO. 1

Glossary of Terms

Abutment
That part of the valley side against which the levee is constructed. An artificial abutment is sometimes constructed such as a concrete gravity section where there is no suitable natural abutment.

Acre-foot
A unit of volumetric measure that would cover 1 acre to a depth of 1 foot. It is equal to 43,560 cubic feet.

Appurtenant structure
Ancillary features of a levee such as inlet and outlet works, spillways, tunnels, or powerplants.

Baffle block
A block, usually of concrete, constructed in a channel or stilling basin to dissipate the energy of water flowing at high velocity.

Base thickness
Also referred to as base width. The maximum thickness or width of the levee measured horizontally between upstream and downstream faces and normal to the axis of the levee, but excluding projections for outlets, or other appurtenant structures.

Bedrock
The consolidated body of natural solid mineral matter which underlies the overburden soils.

Berm
A nearly horizontal step in the sloping profile of an embankment levee. Also a step in a rock or earth cut.

Borrow area
The area from which material for an embankment is excavated.

Breach
An eroded opening through a levee allowing flood waters to enter. A controlled breach is a constructed opening. An uncontrolled breach is an unintentional opening which allows uncontrolled discharge.

Catastrophe
A sudden and great disaster causing misfortune, destruction, or irreplaceable loss extensive enough to cripple activities in an area.

Channel
A general term for any natural or artificial facility for conveying water.

Compaction
Mechanical action which increases the density by reducing the voids in a material.

Conduit
A closed channel to convey water through, around, or under a levee.

Construction joint
The interface between two successive placings or pours of concrete where bond, and not permanent separation, is intended.

Contact grouting
Filling, with cement grout, any voids existing at the contact of two zones of different materials, e.g., between a concrete tunnel lining and the surrounding rock.

Core
A zone of low permeability material in an embankment levee. The core is sometimes referred to as central core, inclined core, puddle clay core, rolled clay core, or impervious zone.

Core wall
A wall built of relatively impervious material, usually of concrete or asphaltic concrete, in the body of an embankment dam to prevent seepage.

Cross section
An elevation view of a levee formed by passing a plane through the levee perpendicular to the axis.

Cutoff trench
A foundation excavation later to be filled with impervious material so as to limit seepage beneath a levee.

Cutoff wall
A wall of impervious material usually of concrete, asphaltic concrete, or steel sheet piling constructed in the foundation and abutments to reduce seepage beneath and adjacent to the levee.

Design water level
The maximum water elevation including the flood surcharge that a levee is designed to withstand.

Diversion channel, canal, or tunnel
A waterway used to divert water from its natural course. The term is generally applied to a temporary arrangement, e.g., to by-pass water around a site during construction. "Channel" is normally used instead of "canal" when the waterway is short.

Drain, blanket
A layer of pervious material placed to facilitate drainage of the foundation and/or embankment.

Drain, chimney
A vertical or inclined layer of pervious material in an embankment to facilitate and control drainage of the embankment fill.

Drain, toe
A system of pipe and/or pervious material along the downstream toe of a levee used to collect seepage from the foundation and embankment and convey it to a free outlet.

Drainage area
The area which drains to a particular point on a river or stream.

Drainage curtain
Also called drainage wells or relief wells. A line of vertical wells or boreholes to facilitate drainage of the foundation and abutments and to reduce water pressure.

Drawdown
The difference between a water level and a lower water level in a waterway within a particular time. Used as a verb, it is the lowering of the water surface.

Embankment
A raised structure to hold back water or to carry a roadway.

Emergency
An emergency, in terms of levee operation, is a condition which develops unexpectedly, endangers the structural integrity of the levee and/or downstream property and human life, and requires immediate action.

Emergency Action Plan (EAP)
A plan of action to be taken to reduce the potential for property damage and loss of life in an area affected by a levee failure or large flood.

Energy dissipater
A device constructed in a waterway to reduce the kinetic energy of fast flowing water.

Filter (filter zone)
One or more layers of granular material graded (either naturally or by selection) so as to allow seepage through or within the layers while preventing the migration of material from adjacent zones.

Flashboards
Structural members of timber, concrete, or steel placed in channels or on the crest of a spillway to raise the reservoir water level but that may be quickly removed in the event of a flood.

Flood
A temporary rise in water levels resulting in inundation of areas not normally covered by water. May be expressed in terms of probability of exceedance per year such as one percent chance flood or expressed as a fraction of the probable maximum flood or other reference flood.

Floodplain
An area adjoining a body of water or natural stream that has been or may be covered by floodwater.

Freeboard
Vertical distance between the design water level and the top of levee.

Gate
A movable, watertight barrier for the control of water in a waterway.

a. *Bascule gate.* See flap gate.

b. Bulkhead gate. A gate used either for temporary closure of a channel or conduit before dewatering it for inspection or maintenance or for closure against flowing water when the head difference is small, e.g., for diversion tunnel closure.

C. *Crest gate (spillway gate).* A gate on the crest of a spillway to control the discharge or reservoir water level.

d. Drum gate. A type of spillway gate consisting of a long hollow drum. The drum may be held in its raised position by the water pressure in a flotation chamber beneath the dam.

e. Emergency gate. A standby or auxiliary gate used when the normal means of water control is not available. Sometimes referred to as guard gate.

f. *Fixed wheel gate 6axed roller gate orfixed axle gate).* A gate having wheels or rollers mounted on the end posts of the gate. The wheels bear against rails fixed in side grooves or gate guides.

g. Flap gate. A gate hinged along one edge, usually either the top or bottom edge. Examples of bottom-hinged flap gates are tilting gates and fish belly gates so called from their shape in cross section.

h. Flood gate. A gate to control flood release from a reservoir.

i. Outlet gate. A gate controffing the flow of water through a reservoir outlet.

j. Radial gate (tainter gate). A gate with a curved upstream plate and radial arms hinged to piers or other supporting structure.

k. Regulating gate (regulating valve). A gate or valve that operates under full pressure flow conditions to regulate the rate of discharge.

1. Roller drum gate. See drum gate.

m. Roller gate (stoney gate). A gate for large openings that bears on a train of rollers in each gate guide.

n. Skimmer gate. A gate at the spillway crest whose prime purpose is to control the release of debris and logs with a limited amount of water. It is usually a bottom hinged flap or Bascule gate.

0. *Slide gate (sluice gate).* A gate that can be opened or closed by sliding in supporting guides.

Geotextiles
Any fabric or textile (natural or synthetic) when used as an engineering material in conjunction with soil, foundations, or rock. Geotextiles have the following uses: drainage, filtration, separation of materials, reinforcement, moisture barriers, and erosion protection.

Groin
The area along the contact (or intersection) of the face of a levee with the abutments.

Grout
A fluidized material that is injected into soil, rock, concrete, or other construction material to seal openings and to lower the permeability and/or provide additional structural strength. There are four major types of grouting materials: chemical, cement, clay, and bitumen.

Grout curtain
One or more zones, usually thin, in the foundation into which grout is injected to reduce seepage under or around a levee.

Grout blanket
An area of the foundation systematically grouted to a uniform shallow depth.

Groutcap
A concrete pad constructed to facilitate subsequent pressure grouting of the grout curtain.

Head, static
The vertical distance between two points in a fluid.

Head, velocity
The vertical distance that would statically result from the velocity of a moving fluid.

Height, above ground
The maximum height from natural ground surface to the top of a levee.

Height, hydraulic
The vertical difference between the maximum design water level and the lowest point in the original streambed.

Height, structural
The vertical distance between the lowest point of the excavated foundation to the top of the levee.

Inclinometer
An instrument, usually consisting of a metal or plastic tube inserted in a drill hole and a

sensitized monitor either lowered into the tube or fixed within the tube. This measures at different points the tube's inclination to the vertical. By integration, the lateral position at different levels of the tube may be found relative to a point, usually the top or bottom of the tube, assumed to be fixed. The system may be used to measure settlement during embankment construction (Bartholomew, Murray, and Goins 1987). A reference benchmark is used to establish the top of the inclinometer casing. The instrument probe is lowered to each slip joint in the casing, and the depth to each joint is read directly off the tape. Settlement measurements are made as each section of casing is added during embankment construction.

Instrumentation
An arrangement of devices installed into or near levees (i.e., piezometers, inctinometers, strain gages, measurement points, etc.) which provide for measurements that can be used to evaluate the structural behavior and performance parameters of the structure.

Intake
Any structure in a reservoir, dam, or river through which water can be discharged.

Inundation map
A map delineating the area that would be flooded by a particular flood event.

Levee failure
The uncontrolled release of water into a protected area. It is recognized that there are lesser degrees of failure and that any malfunction or abnormality outside the design assumptions and parameters which adversely affect a levee's primary function of impounding water is properly considered a failure. They are, however, normally amenable to corrective action.

Levee Safety
This term not only covers the safeguarding of human life and property but also the satisfactory operation of the structure. The safety of a levee manifests itself in being free of conditions that could lead to the deterioration or destruction of the levee. The margin which separates the actual conditions of a levee from those leading to its damage or destruction is a measure of its safety. To be safe, a levee has to have appropriate reserves, taking into account all scenarios. .

Levee Safety preparedness
The quality or state of being prepared to deal with emergency conditions which endanger the structural integrity of the levee and/or downstream property and human life.

Length of Levee
The length along the top of the levee. This also includes the spillway, powerplant, navigation lock, fish pass, etc., where these form part of the length of the levee.

Liquefaction
A condition whereby soil undergoes continued deformation at a constant low residual stress or with low residual resistance, due to the buildup and maintenance of high pore water pressures, which reduces the effective confining pressure to a very low value. Pore pressure buildup leading to liquefaction may be due either to static or cyclic stress applications and the possibility of its occurrence will depend on the void ratio or relative density of a coliesionless or slightly cohesive soil and the confining pressure.

Maximum flood control level
The highest elevation of the flood control storage.

Maximum pool
The highest pool elevation resulting from the inflow design flood.

Maximum wave
The highest wave in a wave group.

Observation well
A hole used to observe the groundwater surface at atmospheric pressure within soil or rock.

Outlet
An opening through which water can be discharged.

Outlet works
A device to provide controlled releases.

Parapet wall
A solid wall built along the top of a levee (upstream or downstream edge) used for ornamentation, for safety of vehicles and pedestrians, or to prevent overtopping caused by wave runup.

Phreatic surface
The free surface of water seeping at atmospheric pressure through soil or rock.

Piezometer
An instrument used for measuring fluid pressure (air or water) within soil, rock, or concrete.

Piping
The progressive development of internal erosion by seepage.

Plunge pool
A natural or artificially created pool that dissipates the energy of free falling water.

Pore water pressure
The interstitial pressure of water within a mass of soil, rock, or concrete.

Probability
The likelihood of an event occurring.

Riprap
A layer of large uncoursed stone, precast blocks, bags of cement, or other suitable material, generally placed on the upstream slopes of an embankment or along a watercourse as protection against wave action, erosion, or scour. Riprap is usually placed by dumping or other mechanical methods and in some cases is hand placed. It consists of pieces of relatively large size as distinguished from a gravel blanket.

Runup
The vertical distance above the setup that the rush of water reaches when a wave breaks on the levee embankment.

Seepage
The interstitial movement of water that may take place through a levee, its foundation, or its abutments.

Slope
Inclination from the horizontal. Sometimes referred to as batter when measured from vertical.

Sluice
An opening for releasing water from below the static head elevation.

Spillway
A structure over or through which flow is discharged. If the rate of flow is controlled by mechanical means such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway.

Spillway, auxiliary

Any secondary spillway, which is designed to be operated very infrequently and possibly in anticipation of some degree of structural damage or erosion to the spillway during operation.

Spillway, primary (or service)
A spillway designed to provide continuous or frequent releases without significant damage to either the levee or its appurtenant structures.

Spillway channel
An open channel or closed conduit conveying water from the spillway inlet downstream.

Spillway chute
A steeply sloping spillway channel that conveys discharges at supercritical velocities.

Spillway crest
The lowest level at which water can flow over or through the spillway.

Stilling basin
A basin constructed to dissipate the energy of rapidly flowing water, e.g., from a spillway or outlet, and to protect the riverbed from erosion.

Stoplogs
Large logs, timbers, or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit so as to provide a cheaper or more easily handled means of temporary closure than a bulkhead gate.

Storage
The retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of overflow areas, as in the progression of a flood wave through a natural stream channel. Storage definitions are as follow:

a. Dead storage. The storage that ties below the invert of the lowest outlet and that, therefore, cannot readily be withdrawn from the reservoir.

b. Inactive storage. The storage volume of a reservoir between the crest of the invert of the lowest outlet and the minimum operating level.

C. Active storage. The volume of the reservoir that is available for some use such as power generation, irrigation, flood control, or water supply. The bottom elevation is the minimum operating level.

d. Live storage. The sum of the active and the inactive storage.

e. Reservoir capacity. The sum of the dead and live storage of the reservoir.

f. *Flood* surcharge. The storage volume between the top of the active storage and the design water level.

Toe of Levee
The junction of the face of a dam with the ground surface. For concrete dams, see heel.

Top of levee
The elevation of the uppermost surface of a levee, usually a road or walkway excluding any parapet wall, railing, etc.

Uplift
The uplift pressure in the pores of a material (interstitial pressure) or on the base of a structure.

Valve
A device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway so as to control or stop the flow.

a. Hollow jet valve. A device for regulating high-pressure outlets. Essentially, it is half a needle valve in which the needle closure member moves upstream toward the inlet end of the valve to shut off flow. As there is no convergence at the outlet end, the flow emerges in the form of an annular cylinder, segmented by several splitter ribs for admitting air into the jet interior to prevent jet instability.

b. Regulating sleeve valve. A valve for regulating high pressure outlets and ensuring energy dissipation. Inside the valve there is a fixed-cone, pointed upstream, which ensures dispersion of the jet.

Outside the valve a cylindrical sleeve moves downstream to shut off flow by sealing on the periphery of the cone.

Volume of levee
The total space occupied by the materials forming the levee structure computed between abutments and from top to bottom of dam.

Watershed divide
The divide or boundary between catchment areas (or drainage areas).

Waterstop
A strip of metal, rubber, or other material used to prevent leakage through joints between adjacent sections of concrete.

Weir
A notch of regular form through which water flows.

a. Weir, broad-crested. An overflow structure on which the nappe is supported for an appreciable length in the direction of flow.

b. Weir, nteasuring. A device for measuring the rate of flow of water. It generally consists of a rectangular, trapezoidal, triangular, or other shaped notch, located in a vertical, thin plate over which water flows. The height of water above the weir crest is used to determine the rate of flow.

C. *Weir, ogee.* A reverse curve, shaped like an elongated letter "S." The downstream faces of overflow spillways are often made to this shape.

Wind setup
The vertical rise in the still water level at the face of a structure or embankment caused by wind stresses on the surface of the water.

EXHIBIT NO. 2

LIST OF ACRONYMS

a.f: acre-feet
approx.: approximate
Apr: April
AS: Anti Skid
Aug: August
ave.: Average
AWWA: American Water Works Association
cap.: Capacity
CFR: Code of Federal Regulations
cfs: cubic feet per second
Cfs: cubic feet per second
CMP: corrugated metal pipe
CO: Carbon Monoxide
COE: Corps of Engineers
CPR: Cardio Pulmonary Resuscitation
cu. Yds. (cy): cubic yards
Dec: December
dia.: diameter
D/S: downstream
Elev.(el): elevation
ER: Engineering Regulation
Feb: February
fps: feet per second
Ft., FT, ft.: feet
FY: Fiscal Year
gpm: gallons per minute
H: horizontal
I.D.: inside diameter
in.: inch
Jan: January
Jul: July
Jun: June
lb/cft: pounds per cubic foot
LEL: Lower Explosive Limit
Mar: March
max.: maximum
MH: manhole
MH2: Mega Hertzs
min.: minimum
MRBWMD: Missouri River Wide Water Management District
MSL: mean sea level
N: North

NOAA: National Oceanic and Atmospheric Administration
Nos.: numbers
Nov: November
NWS: National Weather Service
Oct: October
O2: Oxygen
P: piezometer
PBM: Permanent Benchmark
PCRS: Permit Required Confined Space
PL: Public Law
PMF: Probable Maximum Flood
PMP: Probable Maximum Precipitation
PPM: parts Per Million
psf: pounds per square foot
psi: pounds per square inch
Pz: piezometer
PVC: poly-vinyl chloride
RCC: Reservoir Control Center
rpm: Revolutions per minute
rt.: right
SCBA: Self Contained Breathing Apparatus
SC: Slope and Crest Movement Marker
SDF: spillway design flood
Sep: September
SG: Settlement Gage
SSHP: Site Safety & Health Plan
sq. In.: square inch
sq. mi.: square mile
sq. yds.: square yards
Sta.: station
T: Inclinometer designation
TOC: table of contents
TV: Television
UP: uplift piezometer
U/S: upstream
U.S.: United States
USACE: United States Army Corps of Engineers
U.S.G.S.: United States Geological Survey
UV: Ultra Violet
V: vertical
Vol: volume
W: West
wt.: weight
yrs.: years

EXHIBIT NO. 3

PROJECT X

Site Safety & Health Plan
(S.S.H.P.)

Template

Date ______________________

Site Safety and Health Plan
For
Project X
Date ________________

Prepared by:____________________________________ ________________
–

Approved by:____________________________________ ______________
–

Approved by: ________________________________

By signing this form,
I certify that I have READ and UNDERSTAND the requirements of this
Site Safety and Health Plan

I also certify that I have attended the required training for confined space and water safety and I agree to comply with all the requirements stated in this

Site Safety and Health Plan

Page 1

Name	Organization	Signature	Current Certificate for: (Yes or No)		
			Confined Space Training?	First Aid and CPR?	Water Safety Training

By signing this form,
I certify that I have READ and UNDERSTAND the requirements of this
Site Safety and Health Plan

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Site Safety and Health Plan

Page 2

Name	Organization	Signature	Current Certificate for: (Yes or No)		
			Confined Space Training?	First Aid and CPR?	Water Safety Training

Site Safety and Health Plan
For
Project X

Table of Contents

APPENDIX

SITE SAFETY AND HEALTH PLAN
FOR
Project X

1. Introduction

1.1. Purpose and Scope of Work.

1.2. Purpose of the Site Safety and Health Plan. During the course of a ____________________, the members of the _____________ team will be faced with a variety of situations, which may cause some concern from a personnel safety standpoint. The inspection team may be faced with situations such as, adverse weather conditions (hot and humid), confined space entry, water safety and general safety issues. The purpose of this Site Safety and Health Plan is to make the inspection team aware of any safety hazards that may exist and to outline procedures and practices, which will assure the safety of all inspection team members. This plan outlines general site concerns, confined space concerns and water safety practices. The plan also includes an assignment of responsibilities, establishes personnel protection standards, mandatory safety practices and procedures, and provides contingencies for problems, which may arise during the ____________________. All inspection team members will be required to sign the Master Copy of this plan to signify that they have read the plan, understand the procedures to be implemented during the inspection and agree to comply with the specified requirements. Before activities associated with the inspection begin, all inspection team members will receive a safety and health briefing to discuss safety procedures and familiarize personnel with the potential hazards at the project.

1.3. Project Features that will be Inspected. Appendix A contains a list of project features which will be inspected, the potential safety concerns associated with that feature and the recommended safety precautions to be taken.

2. General Site Safety. The major concerns with regard to general site safety during the ______________ are the potential for slipping, tripping, and falling type hazards. Team members should exercise caution when walking on riprap, steep slopes, climbing ladders, or other similar type activities. The inspection team may be exposed to insect, snake, small rodents or other types of animal hazards. Team members should avoid any animal that may be encountered, wear appropriate clothing, and use repellent sprays to minimize the potential for animal and insect bites. Cold stress is not anticipated to be a problem during the inspection. However, heat stress could be a problem if the weather during the inspection reaches high temperatures. Precautions against heat stress include wearing loose, light colored clothing, drinking plenty of fluids, resting as necessary to reduce the level of physical activity, and wearing a wide brimmed hat to protect from long exposure to the sun. The use of sun screen is also recommended during the portions of the inspection which requires long exposure to the sun (inspection of the embankment and spillway). Team members should watch other team members for signs of heat stress. No hazardous or toxic substances or materials will be handled during the inspection. All personnel shall be responsible to conform to the appropriate requirements contained in ____________________.

3. Confined Space Safety.

3.1 General. During the ________________, entry or work in confined spaces, as defined in 29 Code of Federal Regulations (CFR) 1910.146, will be required. All entry and activities in confined spaces will be in accordance with Federal law and District policy. **As such, all individuals who enter into confined spaces will have completed formal confined space training prior to the inspection per the requirements of 29 CFR 1910.146.** Prior to the ____________, all team members will be briefed on general personnel safety and confined space entry, which includes egress and emergency situation procedures. All team members will be required to sign a document that indicates that they have received such a briefing and fully understand all procedures and agree to comply with the specified requirements. Individuals that do not complete such documentation will be prohibited from entering the confined space.

3.2. Confined Space Definition. A confined space is an area that meets the following conditions:

- The space is large enough and configured such that an employee can enter and perform the assigned work.
- The space has limited opening for entry and exit.
- The space is not designed for continuous human occupancy.

There are two types of permitted confined space, Category I and Category II, as defined below:

Permit Required Confined Space - Category I (PRCS I). A Category I confined space meets at least one of the conditions listed below which **cannot** be entirely eliminated prior to entering the space:

(a) Contains, or has a known potential to contain, a hazardous atmosphere which cannot be controlled. This includes spaces where the atmosphere is not normally hazardous but may become hazardous due to work activities such as welding or

painting. Any space where the atmospheric conditions become hazardous shall be temporarily classified as a Category I confined space for the duration of such work.
(b) Contains a material with the potential for engulfment.
(c) Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls, or has a floor which slopes downward and tapers to a smaller cross-section.

Permit Required Confined Space - Category II (PRCS II). A Category II confined space is a confined space in which all actual or potential atmospheric hazards **can** be controlled naturally or through mechanical ventilation methods for the entire space. Any physical hazards which would necessitate a Category I confined space designation have been mitigated prior to entry.

3.3. Roles & Responsibilities . Provided below is a listing of various team positions and their associated responsibilities. A tabular listing of individuals assigned to these positions is provided in Appendix B.

3.3.1. Confined Space Coordinator. The Confined Space Coordinator is a employee, designated by _____________________, who is qualified and adequately trained and capable of recognizing, and evaluating employee exposure to hazardous materials and/or other unsafe conditions in a confined space. The Confined Space Coordinator is responsible for the day-to-day confined space practices and procedures for the project and shall maintain a file of all records for the projects confined space program. The Confined Space Coordinator will sign the confined space entry permit.

3.3.2. Confined Space Supervisor. The Confined Space Supervisor is responsible for ensuring that entry conditions are safe and makes certain that all items (e.g., personnel protective equipment) and procedures associated with the confined space entry plan are adhered to. Before the entry, the Confined Space Supervisor verifies that the permit is filled out completely and all safety steps listed are taken. The Confined Space Supervisor then signs the permit form allowing entry. During entry, the Confined Space Supervisor checks conditions to make sure they are safe throughout the work. If conditions become unsafe, the permit is canceled and all Entrants are ordered out of the confined space. The Confined Space Supervisor ensures that any unauthorized people are removed. When the work is finished, the Confined Space Supervisor cancels the permit.

3.3.3. Attendant. An individual located outside a Category I Permit Required Confined Space who is trained to monitor the Authorized Entrants. The Attendants, who must be qualified in first aid and cardiopulmonary resuscitation (CPR), shall remain outside the permit space in a safe area at all times and shall be assigned no other conflicting duties. The Attendants must be able to communicate with those working in the permit space and with others to obtain emergency assistance if necessary. In the event of an emergency, the Attendant shall not enter the permit space until equipped with the proper rescue equipment and until a backup Attendant arrives. The appropriate rescue equipment will be immediately available to the Attendant and the pre-designated backup Attendant will be continuously available in the area.

3.3.4. Authorized Entrant. An individual who is authorized through training to enter into either a Category I or Category II Permit Required Confined Space. Authorized Entrants may rotate duties for a Category I Permit Required Confined Space, serving as Attendants if the associated permit so states. The Authorized Entrant shall adhere to all items and procedures associated with this plan.

3.3.5. Team. The team will consist of ____________________ officials. The team is responsible for conducting the _____________ in a safe manner. This includes following all safety requirements and notifying the Team Leader if safety requirements are being violated.

3.3.6. Team Leader. The Team Leader is responsible for the overall conduct of the _______________ to include scheduling, on-site control, and coordination.

3.3.7. Rescue Team. An "In-House 1st Aid Team" shall be identified (see Appendix B for listing of names and phone numbers) and consist of individuals that are specifically trained to perform assigned 1st aid duties in addition to their general confined space training. In addition to the "In-House 1st Aid Team", professional rescue organizations shall be identified (see Appendix B). **Only professionally trained people shall enter a confined space for the purpose of rescue .**

3.4 Identified Confined Space. Table 1 contains the project's identified confined space that will be entered. No other "confined space" entry will be allowed without employing proper procedures. The inspection team leader (__________________________) shall be notified in advance of any desired confine space entry.

Table 1 Identified Confined Spaces To Be Inspected		
Confined Space, Cat II		Type of Ventilation
	Location	

3.5 Equipment Requirements. The equipment listed in Table 2 will be available for use during entry into or work in any confined space on the project. All equipment will be in good working order. The equipment will be checked and calibrated as necessary for proper function prior to entry into a confined space. **Confined spaces shall NOT be entered or worked in if the equipment is not functioning properly or is not calibrated to manufacturer's standards.**

Table 2 Minimum Confined Space Equipment Requirements	
EQUIPMENT	**Quantity** Supplier(s)
Two-way Radios	
Cellular Phone	
Air Meter: (Combustible Gas, Carbon Dioxide, Methane, Hydrogen Sulfide, and Oxygen)	
Flashlights	
Rubber Boots	

3.5.1 Atmospheric Monitoring Instrument.

- **Air Meter Requirements.** The air meter(s) will be capable of measuring for percent of oxygen, percentage of lower explosive limit, and toxic gases (hydrogen sulfide and carbon dioxide) that could be present in levels immediately dangerous to life or health (IDLH).

- **Air Meter Calibration.** The air meter will be calibrated a maximum of six hours prior to entry into a confined space. The Confined Space Coordinator and/or the Confined Space Supervisor are responsible for calibration before entry into a confined space. The calibration will be performed according to the manufacturer's recommendations and standard gases.

- **Emergency Alarms.** The alarms on the atmospheric monitoring equipment will be set to activate if gas levels are outside of the acceptable ranges specified in Table 3.

Table 3
Confined Space Atmospheric Monitoring Equipment Emergency Alarm Settings

Atmosphere Monitored	Acceptable Range/Level
Combustible Gas	Less than 10% of the LEL
Oxygen	19.5% to 23%
Hydrogen Sulfide	Less than 10 ppm
Carbon Dioxide	Less than 25 ppm

LEL = Lower Explosive Limit
ppm = parts per million

3.5.2 Self Contained Breathing Apparatus. The use of a self contained breathing apparatus (SCBA) is intended only for a Permit Required Confined Space - Category I entry or rescue. Since no Permit Required Confined Space - Category I's have been identified for the inspection, SCBA's will be required only in the event of an emergency and will be supplied and used by the Professional Rescue Team.

3.5.3. Communication Equipment. The two-way radios and cellar phone will be checked for proper functioning immediately prior to entry of a confined space.

3.5.4. Other Equipment. All other equipment will be checked to make sure it is in proper working order.

3.6. Dangerous Conditions. Dangerous air quality conditions exist if any of the following conditions are present:

- Combustible gas levels greater 10 percent of the LEL
- Oxygen levels less than 19.5 percent or greater than 23 percent
- Hydrogen Sulfide levels greater than 10 parts per million
- Carbon Dioxide levels greater than 25 parts per million

If any of the levels described above are exceeded or are outside the specified ranges, entry shall not be allowed into the confined space. If the levels described above are exceeded or are out side the ranges after the inspection team members have entered the confined space, the entrants shall evacuate the confined space immediately.

3.7. Confined Space Entry Procedures. Prior to any confined space entry, the Confined Space Supervisor will perform the following procedures:

- All Authorized Entrants will certify that they have received confined space training pursuant to 29 CFR 1910.146.
- Determine Team members holding a current certification in first aid and CPR.
- Brief all Authorized Entrants in proper confined space entry and work procedures as outlined in this plan.
- Check the working condition of all equipment as outlined in **Section 3.5. Equipment Requirements**.
- Follow the procedures outlined in the following sections for the specific confined space to be entered.
- Fill out appropriate confined space entry form (Appendix D).
- Alert the In-House 1st Aid Team of the intent to enter a confined space and its location.

3.7.1 Site A.

- Determine the Team members that require access to the structure for inspection purposes. Team members that have no inspection responsibilities in the structure will not be allowed to enter.

- The Confined Space Supervisor shall verify that all Team members have valid certification of Confined Space Training or equivalent.
- The Confined Space Supervisor shall verify the outlet works gates are closed, locked out and tagged out.
- The two-way radios and cellular phones will be checked.
- The Confined Space Supervisor shall verify the atmospheric monitoring equipment has been calibrated and is operating properly.
- An Attendant will be designated and assigned a post outside the outlet works tunnels on land (stilling basin). The responsibility of the Attendant will not change during any part of the inspection.
- Emergency procedures will be discussed as outlined in **Section 6, Emergency Procedures.**
- The Confined Space Supervisor will sign the entry permit (Category II, Appendix D) to allow the Authorized Entrants access to the _________.
- An initial Authorized Entrant will not be designated to enter the confined space for this work to monitor the atmospheric conditions prior to the team entering the confined space.
- The Team will then enter the outlet works tunnel while continuously monitoring the atmosphere. The Team will also have a two-way radio to notify the Attendant if any dangerous condition develops.
- The Attendant will monitor to insure that all members of the Team that enter the outlet works tunnel also exit.
- At the completion of the work, the Attendant will certify the entire team has exited.

3.7.2 Site B. The __________________. Steel-toed boots with traction soles will be required to enter the structure. The steps and bottom of the drainage galleries may be extremely slick. Therefore, the Team members shall use extreme caution while conducting the inspection. The drainage galleries are mechanically vented. The structure should be relatively clean and free of any foreign matter that would cause a hazardous atmosphere. However, the atmosphere shall be continuously monitored during the entire inspection. The following procedures will be followed for entry into the spillway structure.

- Determine the Team members that require access to the structure for purposes. Team members that have no inspection responsibilities in the structure will not be allowed to enter.
- Activate the ventilation system.
- The Confined Space Supervisor shall verify that all Team members have valid certification of Confined Space Training or equivalent.
- The two-way radios and cellular phones will be checked.

- The Confined Space Supervisor shall verify the atmospheric monitoring equipment has been calibrated and is operating properly.
- An Attendant will be designated and assigned a post outside the structure. The responsibility of the Attendant will not change during any part of the work.
- Emergency procedures will be discussed as outlined in **Section 6, Emergency Procedures.**
- The Confined Space Supervisor will sign the entry permit (Category II, Appendix D) to allow the Authorized Entrants access to the structure.
- The Team will then enter the structure while continuously monitoring the atmosphere. The Team will also have a two-way radio to notify the Attendant if any dangerous condition develops.
- The Attendant will monitor to insure that all members of the Team that enter the spillway structure also exit.
- At the completion of the inspection, the Attendant will certify the entire team has exited.

4. Water Safety.

4.1. General. The team will be required to work around the water. This includes the inspection of the upstream riprap protection, inspection of the upstream side of the spillway structure and the inspection of the intake structure bridge by a boat. This section contains policies, procedures and requirements for water safety.

4.2. Boat Safety. All inspectors shall have had boater safety training prior to boarding. All inspectors are required to wear personal floatation devices (pfd) at all times while in or near the boat. All inspectors are required to remain seated throughout the coarse of the inspection. Prior to departure of the boat, a float plan shall be developed and filed with the Operations Manager or his representative. In addition to this a briefing will be made to all inspectors prior to boarding.

4.3. Water Safety Procedures. The following procedures will be followed during the inspection of the ________ structure.

- The Team Leader will verify that all Team members have valid certification of water safety training.
- Steel toed boots with traction soles shall be used when walking on the riprap.

5. Personnel Safety Equipment.

The personnel safety equipment specified in Table 4 is required as noted.

Table 4 Personnel Safety Equipment Requirements	
Equipment Supplier	**Applicable**
Steel toed boots, non-slip sole[1]	Entire Inspection
Safety Glasses[1]	As Needed
Gloves[1]	As Needed
Ear Plugs[1,2]	As Needed
Hard Hat[2]	As Needed
Insect Repellent[1]	As Needed

[1] **Supplier**
[2] **Supplier**

6. Emergency Procedures. If an emergency situation occurs, the following procedures will be implemented as applicable. See Appendix C for a listing of the names and phone numbers of the In- House 1st Aid Team and the Professional Rescue Teams.

6.1. Confined Space.

- Evaluate the situation and determine the likely cause of the emergency (e.g. overcome by fumes, non-life threatening situation such as a broken bone).
- If the situation is not the result of dangerous conditions within the confined space, standard action as specified in **Section 6.2, Non-Confined Space** shall be followed.
- **EMERGENCY ACTION - If the situation is the result of a dangerous condition within the confined space such as a toxic atmosphere or of an unknown cause:**

  - ❖ **Attendant shall immediately call the professional emergency response organization as identified.**

  - ❖ **See Appendix C for the names and phone numbers. The Attendant shall notify the designated response team that there is an emergency and that the team will need to extract the individual(s) from the confined**

space. First aid will be administered by qualified in-house or professional emergency response team personnel.

6.2. Non-Confined Space.

- Evaluate the situation and determine if emergency response personnel (In-House and / or professional emergency response) are required. If so, contact the proper authorities and have qualified personnel administer first aid. Appendix D contains a list of emergency points-of-contact.
- If it is not a life-threatening situation, have qualified personnel (inspection first aid team) administer first aid and/or transport individual to a treatment facility if required.

REFERENCES:

29 Code of Federal Regulations (CFR) 1910.146

APPENDIX A

Inspection Hazard Analysis

Inspection Hazard Analysis		
Project Feature to be Inspected	Safety Concerns (Potential Hazards)	Recommended Safety Precautions
Dam Embankment • Crest • Upstream Slope (Riprap) • Downstream Slope • Left Abutment • Right Abutment	Walking on Uneven Surfaces (Slips, Trips & Falls) Hot & Humid Weather (heat stress) Animal Hazards (snakes & other small rodents) Bugs (mosquito's, ticks)	Wear steel toes boots with non-slip soles and take car where you step. Wear loose, light colored clothing. Drink plenty of fluids before and during the inspection. Limit physical activity. Keep an eye on other team members and know the physical signs of heat stress and heat stroke. Stay away from all types of animals. Wear bug spray.
Outlet Works • Control Structure • Downstream Tunnel	**Confined Space Entry** Walking in Water Animal & insects Lifting & Dropping M.H. Covers.	Follow all procedures outlined in Section 3 of this Health and Safety Plan Wear steel toe, non-slip boots. Maintain 3-point support when climbing.
Spillway • Channel • Structure	Walking on Uneven Surfaces (Slips, Trips & Falls) **Confined Space Entry**	Follow all procedures outlined in Section 3 of this Health and Safety Plan Wear steel toe, non-slip boots. Maintain 3-point support when climbing.
Intake Structure	Falling	Stay Behind Guardrails.
	Confined Space Entry Walking in Water Lifting & Dropping M.H. Covers.	Follow all procedures outlined in Section 3 of this Health and Safety Plan Wear steel toe, non-slip boots. Maintain 3-point support when climbing.

APPENDIX B

Inspection Personnel and Responsibilities Chart

Inspection Personnel and Responsibilities Chart	
Designation	Individual
Team Leader	
Confined Space Coordinator	
Confined Space Supervisor	
Attendant	
Inspection Team	
Authorized Entrant	
In-House 1st Aid Organization Professional Emergency Response Organization (required in event of emergency only)	

APPENDIX C

Emergency Points-of-Contact

Emergency Points-of-Contact	
Name/Agency	**Phone Number**
Professional Emergency Response Organizations:	911
Project Office	

APPENDIX D

Entry Permit

CONFINED SPACE - CATEGORY II
ENTRY AUTHORIZATION

UNIT OR AREA -
PERMISSION IS GRANTED TO ENTER :
SCOPE OF WORK TO BE PERFORMED:_________________________

TEST REQUIRED:	**TESTS**	**SAFE LIMITS**
1. Oxygen (02)	_________	19.5 % - 23%
2. Combustible Gases (LEL) (LEL- Lower Explosive Limit)	_________	Less than 10%
3. Carbon Monoxide (CO)	_________	Less than 35 PPM
4. Hydrogen Sulfide (H2S)	_________	Less than 10 PPM
5. Other _________________	_________	______________

SAMPLING REQUIRED: _____ Initial _____Periodic _____ Continuous

INSTRUMENT USED

____

OPERATIONS CHECKLIST: CIRCLE YES OR N/A

1. Has the confined space been drained and purged? Yes N/A
2. Has the confined space been cleaned? Yes N/A
3. Has the confined space been ventilated? Yes N/A
4. Will continuous forced air ventilation be required? Yes N/A
5. Has the confined space been blinded or isolated? Yes N/A
6. Have all energy sources been tagged, locked out, and in zero energy state? Yes N/A
7. Have barriers to prevent unauthorized entry/accidental falls been erected? Yes N/A
8. Has each open entrance been posted with a "Do Not Enter" or copy of entry authorization? Yes N/A
9. Is rescue equipment required? Yes N/A
10. Will entry involved any of the following?:
    - Work which introduces a life-threatening hazard? Yes N/A
    - Any other life-threatening hazard due to confined space? Yes N/A

IF YES to any of the items in number 10 above, complete and attach a "CONFINED SPACE ENTRY PERMIT."

Will hot work be conducted? Yes N/A

If hot work is permitted, the following controls shall be utilized. ____________________________________
____

Other (Special precautions/restrictions):____

SIGNATURE: ___________________________ DATE:___________________ TIME CHECKED:____
Monitor

SIGNATURE:_____________________________ DATE ISSUED:____________ TIME ISSUED:_______
Authorizing Supervisor DATE EXPIRES:___________ TIME EXPIRES:______

DISTRIBUTION:
1. Posted near point of entry
2. Authorizing Supervisor
3. CSC after entry complete

CONFINED SPACE

ENTRY LOG - Outlet Works Control Structure

NAME	IN (TIME)	OUT (TIME)	DATE